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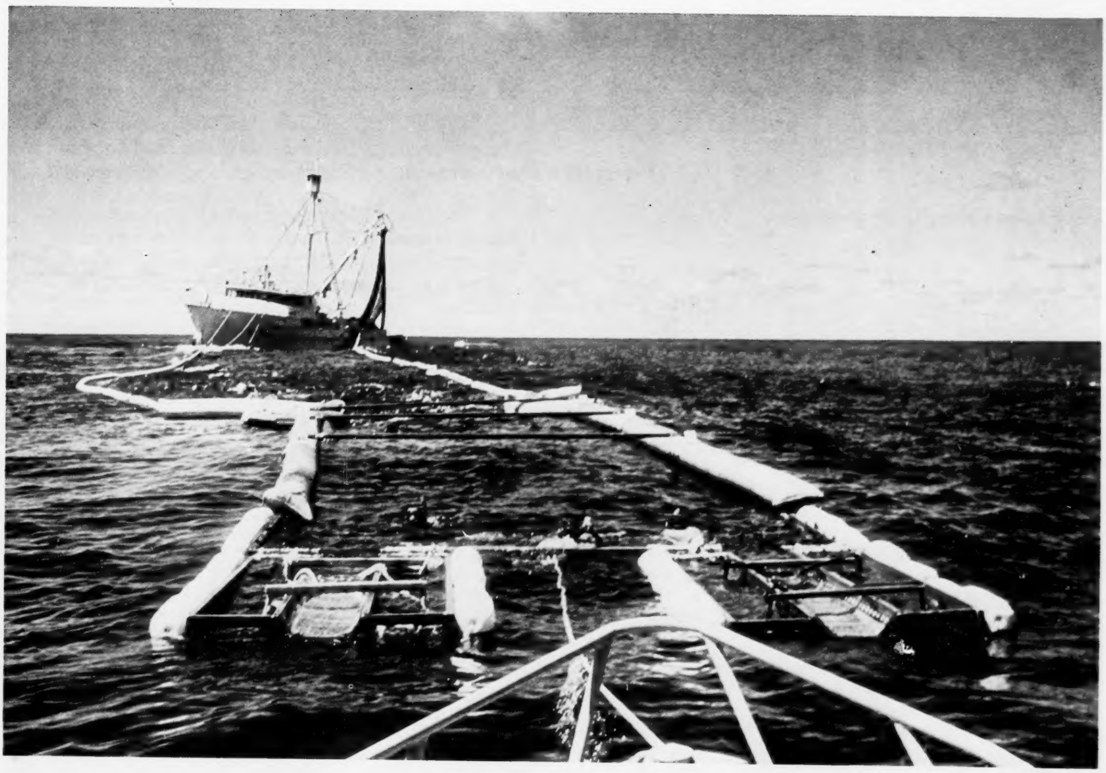

Marine Fisheries REVIEW

On the cover: A corral system for dolphin schools. See the article beginning on page 16.

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A Management Model of the Northwest African Cephalopod Fishery

W. E. GRANT, W. L. GRIFFIN, and J. P. WARREN

Introduction

In 1967 the Food and Agriculture Organization (FAO) of the United Nations established the Fishery Committee for the Eastern Central Atlantic (CECAF). The northwest African fishery, extending from Morocco in the north to Guinea Bissau in the south (FAO Major Fishing Area 34, Fig. 1), is within the jurisdiction of CECAF. This area is particularly rich in fish resources and is fished intensively by both foreign and local fleets (FAO, 1976).

The total annual harvest of all species in the area is about 2.5 million metric

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ABSTRACT—Two versions of a bioeconomic model of the northwest African cephalopod fishery, one assuming an instantaneous natural mortality rate of M = *1.25 on an annual basis and the other a rate of* M = *2.0, predict the harvest of octopus,* Octopus vulgaris; *cuttlefish,* Sepia *spp.; and squid,* Loligo *spp. These predictions are compared with actual harvest data, the sensitivity of model behavior to changes in important biological parameters is examined, and two management schemes for the fishery are evaluated.*

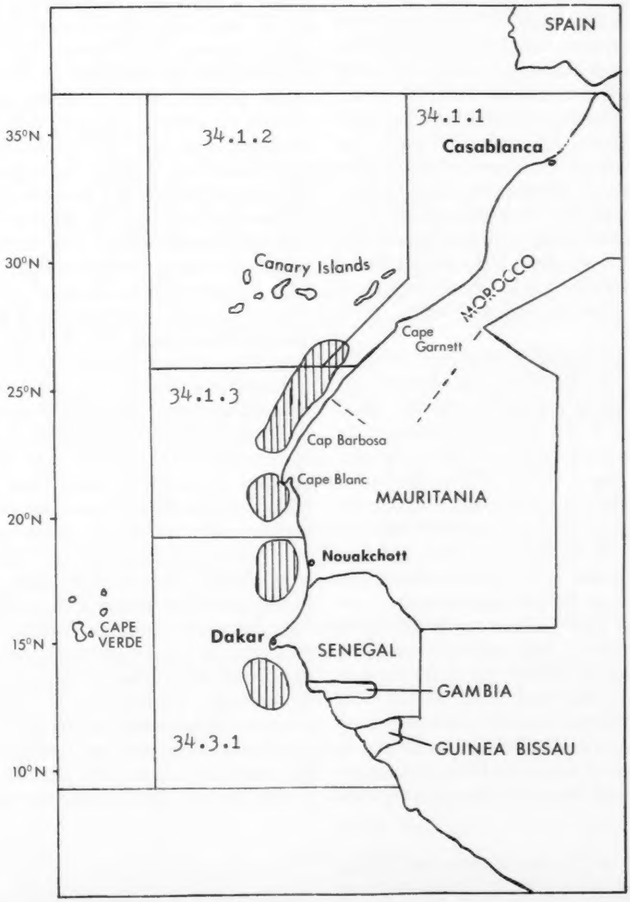

Figure 1.—FAO Major Fishing Area 34 and coastal countries of western Africa. Shaded areas represent main fishing grounds for cephalopods.

tons (t) valued at about US$900 million[1]. In terms of both tonnage (about 200,000 t annually) and commercial value, the cephalopod fishery is the most important fishery in the area and also is one of the most important cephalopod fisheries in the world.

The main species harvested are octopus, *Octopus vulgaris*; cuttlefish, *Sepia officinalis officinalis*, *S. officinalis hierredda*, and *S. bertheloti*; and squid, *Loligo vulgaris* and *L. forbesi*. Fleets harvesting these species consist primarily of trawlers ranging in size from 150 to 550 gross metric tons pulling bottom trawls with mesh sizes ranging from 30 to 70 mm (FAO, 1979).

Historically, international fleets exploited the waters of northwest Africa without restriction. More recently there has been increasing control of fishing through extension of territorial waters and imposition of fishing limits by coastal countries. Of course, fish stocks are not confined within political boundaries, so fisheries management is complicated by the need to coordinate planning on a regional scale. It is anticipated that CECAF will provide the vehicle for regional planning in fisheries management for northwest Africa (Everett, 1976, 1978).

In this regard, a number of research and planning activities, including a plan to simulate mathematically the major biological and economic processes involved in the northwest African fishery, have begun (FAO, 1977). The initial effort in this undertaking involved development of a bioeconomic simulation model of the regional cephalopod fishery (Griffin et al., 1979). This paper reports on further development of the model, which focuses upon the representation of important biological aspects of the fishery, the comparison of model predictions of the harvest with actual harvest data, the examination of the sensitivity of model behavior to changes in important biological parameters, and the use of the model to evaluate two management schemes for the fishery.

The ability of the model to distinguish between harvests predicted by alternate management policies also is evaluated with regard to the effects of biased estimates of important biological parameters and in view of the inherent variability of the fishery. A companion paper[2] discusses the economic and political implications of the management schemes to countries of the region.

Conceptual Model of the Fishery

A simplified representation of the major biological and economic aspects of the northwest African cephalopod fishery is presented in Figure 2. The biological submodel represents the recruitment, growth, natural mortality, and harvest of octopus, *Octopus vulgaris*; cuttlefish, *Sepia* spp.; and squid, *Loligo* spp. Interactions between these species are not well known and have not been represented in the model, although the potential importance of such interactions in the management of multispecies fisheries is recognized (Gulland, 1974; May et al., 1979). Recruitment of individuals of each species into the fishery is a function of environmental factors and is treated as a driving, or external, variable. Clear evidence of a stock-recruitment relationship is lacking (FAO, 1979) and recruitment is assumed to be independent of population size. Once recruited into the fishery, individuals grow and are subjected to both natural and fishing mortality. The latter is a function of the fishing effort exerted within the fishery and is determined in the harvesting sector of the economic submodel as a function of vessel characteristics and days fished. Days fished are determined by the costs of fishing and the selling price of cephalopods. Selling price is determined by supply and demand in the marketing sector. This general approach has been used to construct management-oriented bioeconomic models of other marine fisheries (Blomo et al., 1978; Grant and Griffin, 1979).

Simulation Model Development

Most of the relevant biological information about the northwest African cephalopod fishery has been reviewed recently (FAO, 1979) and we have relied heavily upon this information to set parameters for the simulation model. The majority of the information available pertains to octopus, although some data are available on cuttlefish. Virtually no data have been reported for squid. Economic information about the fishery has been generated from a number of published and unpublished sources as discussed elsewhere (footnote 2).

The simulation model consists of a set of nonlinear difference equations representing the dynamics of the system and has been programmed in FORTRAN for use on a digital computer. The time-step for the model is 1 month; i.e., the difference equations are solved and the state of the system is updated each month of simulated time. Input data required by the model are shown in Table 1.

The basic dynamics of the model result from changes in the number of organisms in the fishery over time:

$$N_{ij}\,(t+1) = N_{ij}\,(t) + \frac{\Delta N_{ij}}{\Delta t} \qquad (1)$$

Table 1.—Input data used in the simulation model.

Item	Item
1. Number of months to be simulated.	6. Parameters of von Bertalanffy growth equation and length-weight conversion equation for each species.
2. Number of species, number of cohorts per year, and number of commercial size classes of organisms.	7. Natural mortality rate and proportion of the population harvested by one real day fished.
3. Number of vessel classes, number of vessels in each class, relative fishing power of each class, and number of nominal days fished per month by vessels in each class.	8. Boundaries between commercial size classes and length of smallest organisms harvested for each species.
4. Initial number, length, and weight of organisms in model at beginning of simulation.	9. Economic data including prices of each species by size class, variable costs associated with fishing, and fixed cost of vessels by vessel class.
5. Magnitude and seasonal distribution of recruitment of organisms into fishery.	

[1]Christy, F. T., Jr. 1979. Economic benefits and arrangements with foreign fishing countries in the northern subregion of CECAF: A preliminary assessment. Draft report for FAO, Dakar, Senegal.

[2]Warren, J. P., W. L. Griffin, and W. E. Grant. Regional fish stock management: A model for northwest Africa. (In prep.)

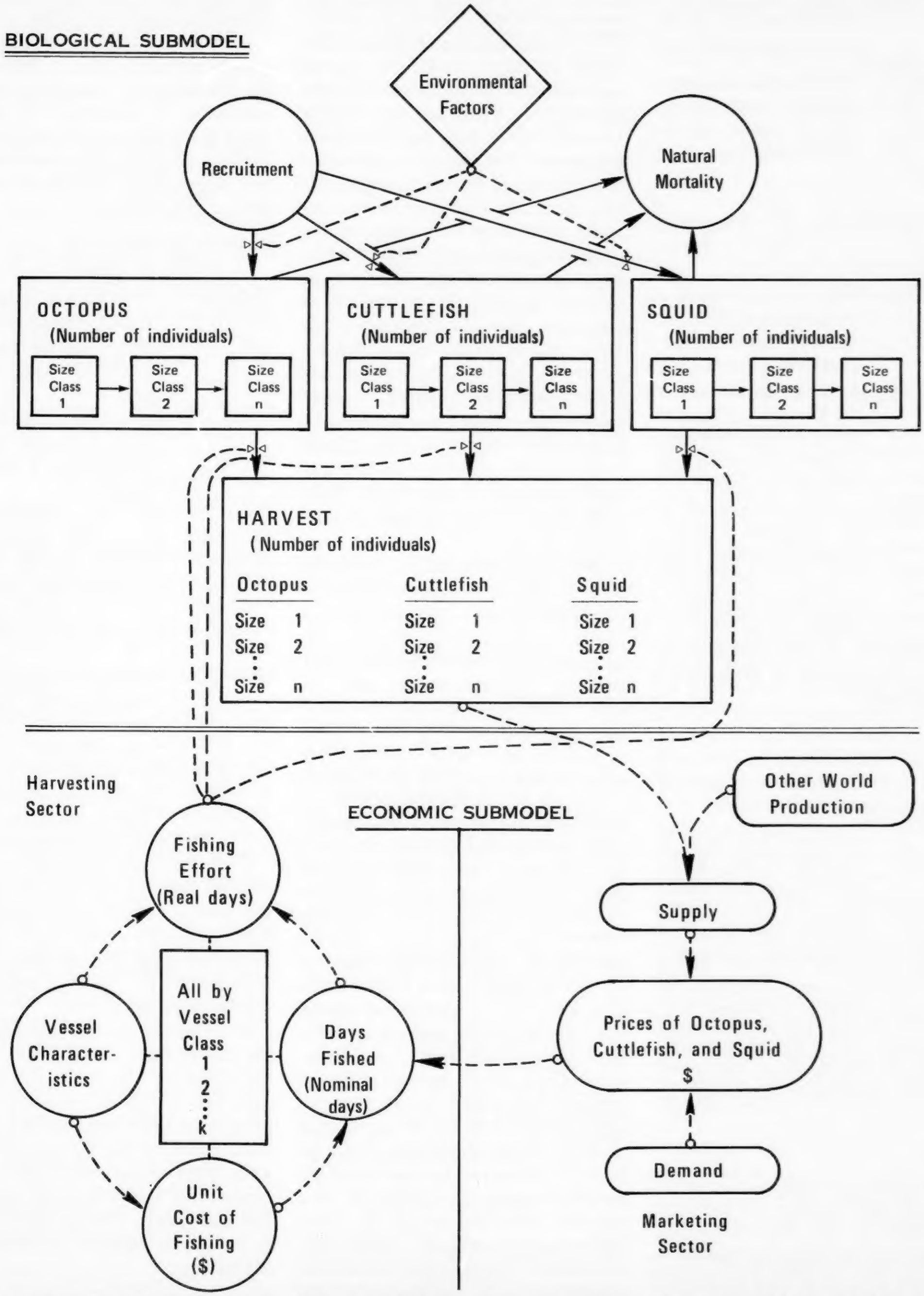

Figure 2.—Simplified representation of the major biological and economic aspects of the northwest African cephalopod fishery. Symbols follow Forrester (1961).

where $N_{ij}(t)$ = number of organisms of the ith species, jth cohort[3] present at time t and

$\frac{\Delta N_{ij}}{\Delta t}$ = net change in number of organisms of the ith species, jth cohort over the time interval t to $t+1$.

$$\frac{\Delta N_{ij}}{\Delta t} = R_{ij} - NM_{ij} - (\sum_{k=1}^{k=m} FM_{ijk}) \quad (2)$$

where R_{ij} = number of individuals of the ith species, jth cohort recruited into the fishery during the time interval,

NM_{ij} = number of individuals of the ith species, jth cohort dying due to natural (nonfishing) causes during the time interval, and

FM_{ijk} = number of organisms of the ith species, jth cohort removed by fishing during the time interval by type k vessels (m = number of vessel classes)[4].

Recruitment of organisms into the fishery is represented as varying on a seasonal basis:

$$R_{ij} = RMAX_i \times S_i \quad (3)$$

where $RMAX_i$ = maximum number of individuals of the ith species that can be recruited into the fishery during one time interval and

S_i = a seasonality factor, $0 \leq S_i \leq 1$, representing the relative magnitude of recruitment of the ith species into the fishery during a given time interval; S_i values for each time interval are specified as input data.

For octopus, recruitment peaks in the spring and again in the fall, whereas cuttlefish recruitment peaks in the spring (FAO, 1979). Squid recruitment is assumed to be relatively high throughout the summer. The absolute magnitude of recruitment and the specific representation of the seasonality of recruitment in the model have been determined by simulation experiments. $RMAX_i$ and S_i have been adjusted such that 1) model behavior is consistent with available information about the dynamics of the fishery and 2) the model is a good predictor of the actual harvests of each species. Octopus are assumed to be recruited into the fishery at a mantle length of 6.43 cm, cuttlefish at 7.64 cm, and squid at 8.64 cm. These recruitment lengths are based on assumptions related to the representation of growth discussed below.

Natural mortality is represented on a species-specific basis as a constant rate per month:

$$NM_{ij} = NMORT_i \times N_{ij} \quad (4)$$

where $NMORT_i$ = proportion of the population of the ith species dying due to natural causes during the time interval.

Although information on natural mortality is sparse, an instantaneous rate of M = 2.0 on a yearly basis has been suggested for octopus in the northwest African fishery (FAO, 1979) and rates between M = 1.00 and M = 1.50 for squid (*Loligo pealei* and *Illex illecebrosus*) off the northeastern United States (Au, 1975). Other short-lived species (i.e., capelin, smelt, and certain minnows) also generally have M>1.0 (Beverton and Holt, 1959). Because of the uncertainty with which natural mortality rates are estimated and the importance of these rates in determining model behavior we developed two versions of the model, one using M = 1.25 (0.1042 on a monthly basis) for each of the three species and one using M = 2.0 (0.1667 on a monthly basis). In addition to these constant mortality rates that are applied independent of age, an upper limit on age is imposed by removing octopus and cuttlefish after they have been exposed to the fishery for 18 months and squid after 12 months (FAO, 1979).

Fishing mortality is represented on a species-specific basis as a function of the abundance of organisms; the susceptibility of organisms to harvest, which is represented as a constant proportion of the population harvested by 1 real (standardized) day fished; and the level of fishing effort:

$$FM_{ijk} = FE_k \times HC_i \times N_{ij} \quad (5)$$

where FE_k = fishing effort in real days fished expended in the fishery during the time interval by type k vessels and

HC_i = proportion of the population of the ith species removed by 1 real day fished.

Fishing effort, in turn, is calculated as the product of the relative fishing power of vessels in the fishery and the number of nominal days fished (days at sea):

$$FE_k = NDF_k \times NVES_k \times RFP_k \quad (6)$$

where NDF_k = number of nominal days fished by the "average" type k vessel during the time interval,

$NVES_k$ = number of type k vessels in the fishery during the time interval, and

RFP_k = relative fishing power of type k vessels[5].

Relative fishing power is calculated as the ratio of catch per day fished by a vessel in the kth vessel class to that of a standard vessel. Relative fishing power is based on 1975 landings data for all species aggregated.

In the model the susceptibility of organisms to harvest is 1.4×10^{-5} for all three species. This value was chosen such that the model simulated appropriately the relationship between annual catch and effort that has been observed since 1969 in the northwest African cephalopod fishery and approximated the appropriate size-class distribution in the harvest based on 1975 data from the fishery.

[3]All organisms of a given species that are introduced into the model in a given month are treated as being identical in terms of size, growth rate, mortality rate, etc., and are designated a cohort.

[4]Note that NM_{ij} and FM_{ij} do not represent the natural mortality coefficient (M) and fishing mortality coefficient (F), respectively, as defined by Gulland (1969) and others. If the time interval t to $t+1$ is indefinitely small, then $NM_{ij} = MNdt$ as discussed by Gulland (1969: 58).

[5]Note that FE_k does not represent the fishing effort exerted by a unit operation (f) as defined by Gulland (1969) and others. $FE_k / NDF_k = f$ as discussed by Gulland (1969:45).

Growth of organisms is represented on a species-specific basis by the von Bertalanffy equation:

$$l_{ij}(t) = L_{\infty ij}\,(1 - e^{-K_{ij}(t_{ij} - t_{0ij})}) \qquad (7)$$

where $l_{ij}(t)$ = mantle length in centimeters of the ith species, jth cohort at time t,
$L_{\infty ij}$ = asymptotic mantle length in centimeters of the ith species, jth cohort,
K_{ij} = coefficient proportional to rate of catabolism based on mantle length in centimeters of the ith species, jth cohort,
t_{ij} = age in years of the ith species, jth cohort, and
t_{0ij} = hypothetical age in years at which mantle length of ith species, jth cohort is zero.

All organisms of a given species have the same initial size at recruitment, regardless of the time of year that they enter the fishery. Parameters of the equation for octopus in the northwest African fishery have been estimated by Guerra (FAO, 1979), however, estimates are not available for cuttlefish or squid. Initial parameter values for cuttlefish and squid were assigned based upon the assumption that the growth of these organisms was such that they entered the largest commercial size class at 20 percent of their asymptotic weight, which is the case for octopus; and upon information about their length of life, which suggests a lifespan of 2 years for octopus and cuttlefish and 1 year for squid (FAO, 1979). For squid, these initial parameter values were adjusted to increase growth rate consistent with qualitative information in FAO (1979) and with data on one of the same species (*Loligo forbesi*) off the east coast of North America (Holme, 1974). Parameter values used in the model are presented in Table 2.

The length-weight relationship used in the model to convert number of organisms in the harvest to metric tons in the harvest is of the form:

$$w_{ij} = a l_{ij}^{\,b} \qquad (8)$$

where w_{ij} = weight of the ith species, jth cohort in grams,

Table 2.—Values of parameters of the von Bertalanffy equation ($l = L_\infty(1-e^{-K(t-t_0)})$) and of the length-weight conversion equation ($w = al^b$) used in the simulation model. See text for symbol definitions.

Species	L_∞	K	t_0	a	b
Octopus	40.0	0.72	0.34	0.976	2.691
Cuttlefish	45.8	0.75	0.34	0.147	2.910
Squid	40.0	1.40	0.34	0.229	2.290

l_{ij} = mantle length of the ith species, jth cohort in centimeters, and
a and b = parameters of the model.

Length-weight relationships used were those reported for octopus and cuttlefish in the northwest African fishery by Guerra (FAO, 1979) and for squid (*Loligo forbesi*) off the east coast of North America by Holme (1974) (Table 2).

Economic considerations are linked to the biological dynamics of the fishery through fishing effort and the harvest (Fig. 2). Amount of fishing effort is determined external to the model based on historical levels of effort expended in the fishery (footnote 2) and is used as a driving variable. In the marketing sector the price of cephalopods is given for each size-class of each species. Unit costs of fishing are taken from budgets developed by size-class of vessels (footnote 2). The unit cost is defined as the sum of variable and fixed costs per vessel per month. Variable cost for a given class of vessel is calculated as the product of variable cost per day fished, number of days fished, and the number of vessels:

$$VC_k = C1_k \times NDF_k \times NVES_k \qquad (9)$$

where VC_k = variable cost of a vessel of class k and
$C1_k$ = variable cost per day fished per vessel of class k.

Fixed cost for a given class of vessel is the product of the fixed cost per vessel and the number of vessels:

$$FC_k = C2_k \times NVES_k \qquad (10)$$

where FC_k = fixed cost of the k class vessels and
$C2_k$ = fixed cost per vessel of class k.

Total cost for a given vessel class is the sum of the variable and fixed costs:

$$TC_k = VC_k + FC_k. \qquad (11)$$

Rent to the fishery obtained by a given vessel class is the difference between the total revenue and total cost:

$$RENT_k = TR_k - TC_k \qquad (12)$$

where $TR_k = \sum_{i=1}^{n} P_i \times TONS_{ik}$,
P_i = price of the ith species in U.S. dollars, and
$TONS_{ik}$ = metric tons of the ith species caught by vessel class k.

Model Validation

Validation of the model consisted of two steps. In the first step, values of parameters in each version of the model (with $M = 1.25$ and $M = 2.0$) were specified such that they represented conditions in the northwest African cephalopod fishery during 1975[6]. Comparison of results of 1-year baseline simulation runs under these conditions with actual 1975 harvest data (FAO, 1979) indicates that each version of the model predicts the total harvest and represents the general seasonal dynamics of the harvest of each species reasonably well. Each version predicts the general increase in landings from January through December, somewhat underestimating the actual harvest early in the year and overestimating later in the year (Fig. 3). Estimates of the annual harvest of each species and of total cephalopods are all within 7 percent of actual values, but model predictions are less accurate with regard to the size-class distributions of the harvests (Table 3). Predicted harvests of each species contain relatively too many middle-sized organisms and underestimate the proportion of both small and large organisms in the catch.

[6]In specifying parameter values for the two versions of the model, $RMAX_i$ and S_i were adjusted, in the manner described earlier, independently for each version. Thus, the two versions have identical estimates for all parameters except $NMORT_i$, $RMAX_i$, and S_i. However, the behavior of the two versions is not necessarily identical when values of $NMORT_i$, or any other parameter, are varied proportionally. The two versions represent two somewhat different sets of hypotheses concerning the dynamics of the fishery.

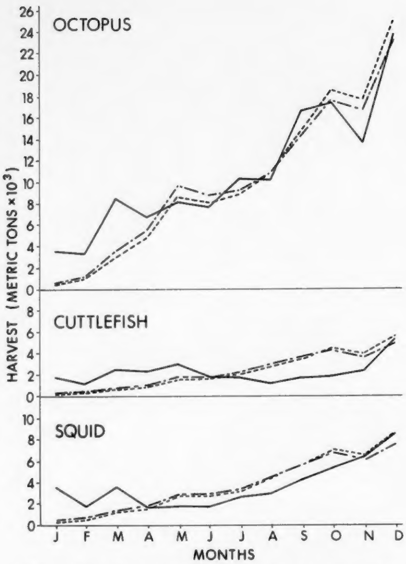

Figure 3.—Comparison of simulated ($M = 1.25$, dash rule; $M = 2.0$, dash/dot rule) and actual (solid rule, based on FAO statistics for 1975) harvests by month of octopus, cuttlefish, and squid.

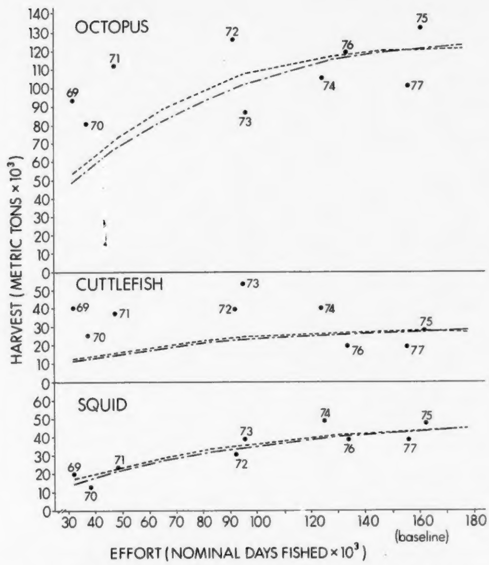

Figure 4.—Comparison of simulated ($M = 1.25$, dash rule; $M = 2.0$ dash/dot rule) and actual (indicated by year based on FAO statistics for 1969 through 1977) annual harvests of octopus, cuttlefish, and squid generated by different levels of fishing effort.

Table 3.—Comparison of simulated and actual (based on FAO statistics for 1975) harvests by size class of octopus, cuttlefish, and squid. Table entries represent simulated minus actual harvest in metric tons and (percent difference).

Species	Size class	$M = 1.25$	$M = 2.0$
Total cephalopods		−10,046(−5)	−9,734(−5)
Octopus	<0.5 kg	−21,386(−47)	−14,757(−32)
	0.5-2.0 kg	17,730(33)	18,312(34)
	>2.0 kg	−5,188(−16)	−11,941(−38)
	Total	−8,845(−7)	−8,387(−6)
Cuttlefish	<0.2 kg	−1,545(−27)	−302(−5)
	0.2-0.7 kg	861(6)	1,539(12)
	>0.7 kg	−407(−4)	−2,116(−23)
	Total	−1,090(−4)	−880(−3)
Squid	<0.1 kg	−3,132(−38)	−1,891(−23)
	0.1-0.4 kg	12,560(58)	12,468(57)
	>0.4 kg	−9,533(−66)	−11,037(−76)
	Total	−104(−<1)	−460(−1)

In the second validation step, several additional simulations in which the level of fishing effort was adjusted from 20 to 110 percent of baseline were run and the annual harvests predicted by each version of the model at each effort level were compared with the actual annual harvests associated with similar levels of effort based on FAO historical data. Predictions of each version of the model compare favorably with actual harvests from 1969 to 1977 (Fig. 4)[7]. One difficulty in estimating the actual effort curves results from the absence of data on the fishing effort exerted on each species. Effort figures reflect days fished for all cephalopods, while harvest data are reported by species. Thus, although vessels may be directing effort toward certain types of cephalopods, there is no basis for representing this in the analysis. For the present analysis it was assumed that effort was directed equally toward all species.

Sensitivity Analysis

Each version ($M = 1.25$ and $M = 2.0$) of the baseline model was subjected to a sensitivity analysis (Smith, 1970) to determine the relative influence of different parameters on model predictions of the annual harvest of each species[8]. Parameters for which relatively good estimates are available were increased, one at a time, by 10 percent of their baseline values and parameters for which little information is available were increased by 100 percent. Among the parameters for which relatively good information is available, model predictions of annual harvests are most sensitive to changes in the exponent of the length to weight conversion equation (b) (Table 4). Among the parameters for which little information is available, model predictions are most sensitive to changes in recruitment rate, but also are sensitive to changes in natural mortality rate (M). Predicted annual harvest of each species responds similarly to most parameter changes.

Illustrative Use of the Model

Evaluation of Alternative Management Policies

To demonstrate the utility of the

[7]Note that fishing effort in Figure 4 is expressed as nominal days fished because estimates of real days fished are not available, except for 1975.

[8]Sensitivity analysis focused on the biological parameters in the model. Economic parameters, such as the market price of cephalopods, variable costs associated with fishing, and fixed costs of vessels, were held constant during all simulations.

model within a decision-making framework, the effects of two management schemes on the harvest of cephalopods were simulated using each version of the model and compared with the baseline, or "present management," situation. Simulation of a management scheme that closes the cephalopod fishery for the period of peak recruitment during April and May, but does not alter fishing effort during the 10-month open season, indicates increased annual harvests relative to baseline for all three species (Table 5). The version of the model with M = 1.25 predicts slightly larger increases than the version with M = 2.0. Harvesting efficiency in the fishery also is increased: 1.68 (M = 1.25) or 1.61 (M = 2.0) t being caught per 1 real day fished compared with 1.16 (both versions) under baseline conditions. The increased yield of each species results from a shift in the size-class distribution of the catch toward larger sized animals. The harvest of squid increases less than the harvests of octopus and cuttlefish due, at least in part, to the relationship between periods of peak recruitment and the period of closure. April and May are the 2 months of highest recruitment for both octopus and cuttlefish, with only 1 other month exhibiting equally high recruitment (September for octopus and June for cuttlefish). In contrast, squid recruitment is highest from May through September, and October recruitment equals April recruitment. Thus, squid are relatively less "protected" by the closure than are octopus and cuttlefish. Seasonal trends in the harvests of all three species after the April-May closure parallel the harvests during these months under the baseline situation.

Table 4.—Results of sensitivity analysis indicating percent error in predicted annual harvests of octopus, cuttlefish, and squid resulting from an overestimation of either 10 or 100 percent in the indicated parameter. Relative sensitivity, indicated parenthetically, is obtained from percent error by setting the largest error in a given column equal to one.

Parameter	Percent change	M = 1.25 Octopus	M = 1.25 Cuttlefish	M = 1.25 Squid	M = 2.0 Octopus	M = 2.0 Cuttlefish	M = 2.0 Squid
L	10	29(0.29)	32(0.26)	24(0.24)	29(0.29)	32(0.27)	24(0.24)
K	10	23(0.23)	24(0.20)	16(0.16)	23(0.23)	25(0.21)	16(0.16)
t_0	10	−15(−0.15)	−15(−0.12)	−12(−0.12)	−16(−0.16)	−16(−0.13)	−14(−0.14)
a	10	10(0.10)	10(0.08)	10(0.10)	10(0.10)	10(0.08)	10(0.10)
b	10	99(1.00)	123(1.00)	97(0.98)	96(0.97)	120(1.00)	95(0.96)
Relative fishing power	10	1(0.01)	−1(−0.01)	2(0.02)	1(0.01)	1(0.01)	2(0.02)
Recruitment rate	100	98(0.99)	98(0.80)	99(1.00)	99(1.00)	98(0.82)	99(1.00)
M	100	−44(−0.44)	−45(−0.36)	−38(−0.38)	−58(−0.58)	−61(−0.51)	−53(−0.53)
HC	100	−14(−0.14)	−18(−0.15)	2(0.02)	−4(−0.04)	−10(−0.08)	10(0.10)
Organisms initially in model	100	2(0.02)	2(0.02)	1(0.01)	1(0.01)	1(0.01)	1(0.01)

Table 5.—Comparison of harvests by size class of octopus, cuttlefish, and squid with 1) an April-May closed season and 2) a 40 percent reduction in the number of nominal days fished each month with harvest predicted under baseline conditions. Table entries represent harvest with a 1) closed season or 2) 40 percent reduction in effort minus baseline harvest in metric tons and (percent difference).

Species and size class		M = 1.25 April-May closure	M = 1.25 −40% effort	M = 2.0 April-May closure	M = 2.0 −40% effort
Total cephalopods		24,455(13)	−26,217(−14)	15,893(8)	−33,029(−17)
Octopus	<0.5 kg	−6,586(−27)	−8,846(−36)	−8,419(−27)	−11,294(−36)
	0.5-2.0 kg	12,810(18)	−11,168(−16)	11,759(16)	−11,929(−17)
	>2.0 kg	12,243(46)	5,106(19)	9,078(46)	3,652(18)
	Total	18,467(15)	−14,908(−12)	12,418(10)	−19,571(−16)
Cuttlefish	<0.2 kg	−1,113(−27)	−1,526(−37)	−1,459(−27)	−1,988(−37)
	0.2-0.7 kg	1,767(12)	−2,581(−18)	1,730(12)	−2,794(−19)
	>0.7 kg	3,353(38)	1,048(12)	2,662(37)	779(11)
	Total	4,007(15)	−3,059(−11)	2,933(11)	−4,003(−15)
Squid	<0.1 kg	−1,064(−21)	−2,065(−40)	−1,320(−21)	−2,562(−40)
	0.1-0.4 kg	818(2)	−7,080(−21)	326(1)	−7,481(−22)
	>0.4 kg	2,227(44)	895(18)	1,536(44)	588(17)
	Total	1,981(4)	−8,250(−18)	542(1)	−9,455(−21)

Table 6.—Comparison of revenues, costs, and rents in millions of U.S. dollars obtained under 1) baseline conditions, 2) an April-May closed season, and 3) a 40 percent reduction in the number of nominal days fished each month.

Revenue, cost, and rent	M = 1.25 Baseline	M = 1.25 April-May closure	M = 1.25 −40% effort	M = 2.0 Baseline	M = 2.0 April-May closure	M = 2.0 −40% effort
Revenue	629	699	535	631	676	517
Cost	626	541	376	626	541	376
Rent	3	158	159	5	135	141

Simulation of a management scheme that reduces the number of nominal days fished each month by 40 percent (achieved by limiting the number of vessels active in the fishery) indicates a decreased annual harvest relative to baseline for each species (Table 5). The version of the model with M = 1.25 predicts slightly smaller decreases than the version with M = 2.0. Harvesting efficiency is increased, however, from 1.16 (both versions) to 1.56 (M = 1.25) or 1.51 (M = 2.0) t caught per 1 real day fished. As in the April-May closure case, the size-class distribution of the harvest for each species is shifted toward larger sized animals, and seasonal trends in the harvests of all three species parallel baseline trends.

Comparison of economic aspects of the fishery indicates a substantial increase in rent (=revenue−costs) relative to baseline under each of the management policies (Table 6). Under the April-May closure policy, revenue is increased 11 percent (M = 1.25 version) or 7 percent (M = 2.0 version), and cost is reduced, because the same number of vessels are fishing fewer days per year, 14 percent (both versions). Under the 40 percent reduced effort policy, revenue is reduced 15 percent (M = 1.25) or 18 percent (M = 2.0), and cost is reduced, because fewer vessels are active in the fishery, 40 percent (both versions).

Robustness of Model Predictions

The ability of each version of the model to distinguish between harvests under alternate management schemes if original estimates of important biological parameters actually are too high or too low also was evaluated. A series of simulations were run in which the point

estimates for rates of recruitment, natural mortality, and the proportion of the population harvested by 1 real day fished were adjusted, one at a time, over a relatively large range of values. When point estimates for rate of recruitment are varied from 0.2 to 2 times the baseline value, total harvests predicted by both versions of the model under the April-May closure policy remain higher, and total harvests predicted under the 40 percent reduced effort policy remain lower, than predicted baseline harvests over all test values (Fig. 5).

When natural mortality rates are varied from 0.2 to 10 times the baseline value, total harvests predicted under the 40 percent reduced effort policy remain lower than baseline over all test values, but harvests predicted under the April-May closure policy are higher than baseline for the lower test values and lower than baseline for the higher test values (Fig. 5). Harvests predicted under April-May closure and baseline policies are equal at natural mortality rates approximately 3 ($M = 1.25$ version) or 1.8 ($M = 2.0$ version) times higher than the rates used in the original model.

The relationship of the three policies with regard to total harvest varies as the proportion of the population harvested by 1 real day fished, which is indicative of fishing mortality rate, is varied from 0.2 to 10 times the baseline value (Fig. 5). Although the shapes of the curves relating total harvest to fishing mortality rate are similar, both versions of the model predict the largest harvest under the April-May closure policy for lower test values and under the 40 percent reduced effort policy for higher test values. Predicted harvest under the baseline policy is larger than the 40 percent reduced effort policy for lower test values, but smaller for higher test values.

Statistical Comparisons of Alternative Management Policies

To enable statistical comparisons of harvests under the different management policies, each version of the model was stochasticized by allowing the rates of recruitment ($RMAX_i$, Equation (3)) and natural mortality ($NMORT_i$, Equation (4)) and the proportion of each population harvested by 1 real day fished (HC_i, Equation (5)) to vary by ± 50 percent of their deterministic values each month. This was done by generating a uniform random variable on the interval 0 to 1, adding 0.5 to the random variable, and multiplying the deterministic value of the rate to be stochasticized by the resulting number. A new random variable was generated each time a rate was stochasticized and the random number generator was seeded differently for each of the three values, recruitment, natural mortality, and proportion harvested by 1 real day fished, for each simulation. Twenty-five simulations were run representing each of the three alternatives. The 25 total cephalopod harvests predicted under each management scheme formed a set of independent, identically distributed, random variables. Results of 2-sample t tests (Snedecor and Cochran, 1967) comparing the two hypothetical management schemes with the baseline situation indicate that the total harvest of cephalopods predicted by both versions of the model is increased significantly ($P<0.001$) under the April-May closure policy and decreased significantly ($P<0.001$) under the 40 percent reduced effort policy.

Summary and Discussion

The current model of the northwest African cephalopod fishery, as part of the initial research and planning activities of FAO, is particularly useful in at least three ways. First, sensitivity analysis of the model identifies those parameters to which model behavior is most responsive (Table 4) and helps to identify, within a quantitative framework, the areas where data crucial to regional planning decisions are lacking. This information is useful not only in establishing future research priorities, but also in determining how much confidence should be placed in model predictions based on the confidence with which the most influential parameters have been estimated (Kowal, 1971). For the cephalopod fishery, additional data on rates of recruitment appear particularly important, although, in terms of evaluating alternate management policies, this information may be somewhat less crucial than suggested by sensitivity analysis (as discussed below). New data on rate of natural mortality and on the amount of fishing effort directed toward each species also appear critical.

Second, as a result of model validation procedures the dynamic relationship of the harvest to rates of recruitment, growth, natural mortality, and fishing mortality within the cephalopod fishery is better understood. Reliable estimates of all these rates are not available for the species under consideration here and such rates are known with confidence for very few, if any, commercially important marine stocks. Although the present model accurately predicts total harvest of cephalopods by species (Table 3) and reflects the general seasonal dynamics of the harvest (Fig. 3), one apparent shortcoming is the lack of correspondence between the size-class distributions of animals in the simulated harvests and those of animals in the actual harvests (Table 3). This discrepancy results primarily because recruitment rates cannot be adjusted relative to literature-based estimates of growth, natural mortality, and fishing mortality, such that both 1) size-class distributions are appropriate and 2) catch/effort relationships accurately represent historical catch/effort relationships over the range of effort levels for which data are available (Fig. 4). The rapid rates of growth and relatively high natural mortality rates that are suggested for cephalopods in the northwest African fishery (FAO, 1979) imply that high fishing mortality rates would be required to catch the proportions of small octopus, cuttlefish, and squid in the actual harvests. When such high fishing mortality rates are used in the model to obtain appropriate size-class distributions in the harvests, the total simulated harvests are far greater than the actual harvests. It is suggested that both natural and fishing mortality rates of cephalopods change with age (FAO, 1979) and this represents a further refinement that might be incorporated into the model as more information becomes available.

Finally, use of the model to evaluate management schemes suggests a general type of management strategy for the cephalopod fishery that warrants further consideration and also provides insight into the degree of uncertainty that must accompany current decisions regarding management alternatives. Initial comparisons of the three policies suggest that both harvesting efficiency and rent in the fishery are increased

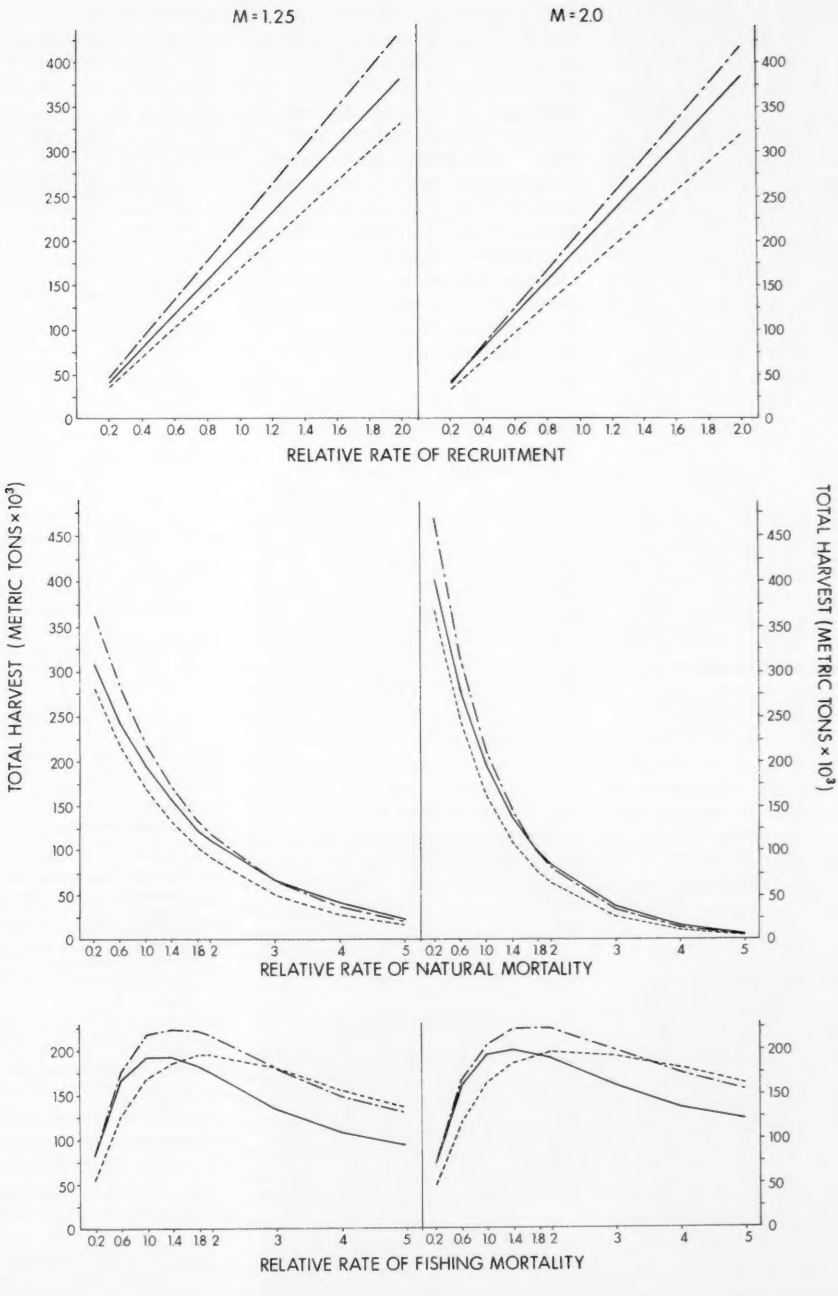

Figure 5.—Effects of changing point estimates for rates of recruitment, natural mortality, and fishing mortality on the total harvest of cephalopods predicted with 1) an April-May closed season (dash/dot rule), 2) a 40 percent reduction in the number of nominal days fished each month (dash rule), and 3) baseline conditions (solid rule). Rates are represented relative to those used in the original model.

relative to baseline by uniformly reducing fishing effort by 40 percent throughout the year or by closure of the fishery during April and May. However, 40 percent reduction of effort significantly decreases total harvest and revenue, whereas April-May closure significantly increases total harvest and revenue, relative to the baseline situation. These predictions allow for a relatively high degree of variability in rates of recruitment, natural mortality, and fishing mortality within the fishery. That is, confidence in the predictions does not depend upon correct representation of the true variability of these important variables unless we believe that they vary by more than ±50 percent of their estimated values each month due to chance; or, more strictly, due to processes or events not represented in the model. Estimates of the variability inherent in most biological processes of importance in marine fisheries are lacking. We have assumed that ±50 percent in any given month is a liberal estimate. Of course, the ability of the model to distinguish between alternative management policies lessens as the amount of variability represented increases.

Also of interest when interpreting model results is the question of whether outcomes of the policy comparisons are changed if estimates of important variables are, in reality, either too high or too low. In this regard, the three policies maintain the same relationship to each other concerning magnitude of total harvest over a wide range of values for recruitment rate (Fig. 5). Thus, although model behavior is sensitive to the estimate of recruitment, as indicated by sensitivity analysis (Table 4), ability to rank the policies with regard to total harvest is unaffected by the accuracy of this estimate unless the actual rate of recruitment is less than 20 percent of the original estimate. This is not the case for estimates of rates of natural or fishing mortality.

Ability to rank the 40 percent reduced effort and baseline policies with regard to total harvest is unaffected by the accuracy of the estimate of natural mortality rate if the actual rate is between 20 and 500 percent of the original estimate (Fig. 5). However, ranking of the April-May closure and baseline policies changes if the actual rate of natural mortality is more than roughly 1.8 (M = 2.0 version) or 3 (M = 1.25 version) times higher than the original estimate. Likewise, ability to rank the April-May closure and baseline policies is unaffected by the accuracy of the estimate of fishing mortality rate if the actual rate is between 20 and 500 percent of the original estimate, although differences between policies become negligible as the estimates become small. But ranking of the 40 percent reduced effort and baseline policies changes if the actual rate of fishing mortality is more than roughly 1.4 (M = 1.25 version) or 1.8 (M = 2.0 version) times higher than the original estimate.

In conclusion, it appears that management schemes which reduce fishing effort on a seasonal basis have potential for increasing total harvest and harvesting efficiency, as well as revenue and rent, in the northwest African cephalopod fishery. To the extent that a closed season of 1.5-2 months duration can be timed to coincide with the period of peak recruitment into the fishery, increases will be maximized. Confidence in this prediction rests on assumptions that the actual recruitment rate into the fishery and the actual fishing mortality rate are both at least 20 percent of the estimated rates, that the actual natural mortality rate is less than 1.8 times the estimated rate, and that actual rates of recruitment, natural mortality, and fishing mortality do not vary due to chance by more than ±50 percent of their estimated values each month.

Acknowledgments

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Demonstration of Advances in Virgin Islands Small Boat Fishing Techniques

DAVID A. OLSEN and JOSEPH A. LaPLACE

Introduction

Virgin Islands fishery development has been forced to face several difficult problems. The first and most important is a growing suspicion that the fishery resources of the Virgin Islands-Puerto Rico shelf may already be overexploited. At present this suspicion is based on incomplete data, but as more information becomes available from a 1975-instituted catch reporting program (Olsen et al., 1975), quantitative statements may be possible.

The second problem is, in part, derivative from the first. The investment potential of local fishermen is not much greater than present levels. Previous development attempts to introduce new techniques for fishing red snapper and grouper resources (Brownell and Rainey, 1972) were unsuccessful because local fishermen felt that they required larger fishing platforms and expensive equipment.

As a consequence, Virgin Islands development programs have concentrated in the areas of diversification and technology introduction at the traditional boat size. The goals of the former (reduction of effort on any single resource) have been met by the development of a deepwater snapper and grouper fishery (Brownell and Rainey, 1972) and more recently by investigations into the resource potential of a portunid crab population (Olsen et al., 1978).

The goal of technology introduction is more complex. Since the assumption of full- or overutilization of the resource is being made, this aspect of the program seeks to make the economics of present exploitation levels more advantageous to the fisherman and the local community. In the Virgin Islands, this aspect of the program has taken the direction(s) of improving marketing from the current roadside sales (Fig. 1) through encouraging formation of cooperatives (Williams, 1976), testing small boat designs and construction techniques, and measuring catch improvements resulting from intensified and diversified fishing formats.

Development efforts have also been taken to introduce new techniques which have already undergone rigorous field testing in local conditions. In this manner local government can save the fishing community the expense of gear testing. Successful techniques (Olsen et al., 1975) can be passed on to the fisherman and unsuccessful methods can be discarded.

This report is a summary of a project in which a new (to the Virgin Islands) boat design was constructed locally and fished on a full-time basis. The records of catch and expense were compiled and extrapolated to supply a financial picture equivalent to local commercial operations. The gross and net incomes were then compared with reported gross catches from Virgin Islands commercial fishermen for 1974-75 and with records from a successful local fisherman for the period from 1963 until 1974.

Material and Methods

Fishing was undertaken from two boats. The first was a 12-year-old, 20 foot × 5

Figure 1.—Virgin Islands fishermen generally spend as much as one-third of their time marketing their catch on the street.

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foot boat of local design and construction. It was powered by an 85 horsepower outboard engine. The second was a 14 foot 10 inch × 7 foot modified Oregon dory (Fig. 2) designed by John Palmer (Anonymous, 1972). The design was based on welded aluminum construction which we modified to double-hulled, ½-inch marine plywood with foam core and coated with epoxy and polypropylene cloth. All joints were epoxy glued; fasteners were Monel[1] boat nails and bronze screws. Materials are listed in Table 1. It was powered by a 50 horsepower outboard engine. This design was chosen because it was a rough-water boat that could be rowed, had low power requirements, and a high load capacity. Additionally, we felt that it could be easily constructed by relatively unskilled craftsmen.

These boats were used on regularly scheduled fishing trips between January 1975 and July 1976. By prescheduling the trips, bias in weather conditions was avoided. Each single day's activities were devoted to full-time fishing without experimental or gear testing activities. The activities employed were:

1) Fish traps: Between 10 and 20 fish traps were hauled daily. West Indian fish traps (Brownell and Rainey, 1972) were generally set unbaited.

2) Handline: Two hookrigs with frozen sprat, fry, or cut bait were used when weather permitted.

3) Longline and set lines were set with 20-50 hooks and the same bait as handlines.

4) Trolling with artificial baits was employed running in and out from the fishing grounds and for aggregations of tunas and kingfish.

5) Lobsters were caught in traps, by free diving, and with scuba.

6) Portunid (*Portunus spinamanus*) crabs were caught in small wire traps.

7) Electric reels were employed in deep water for snappers and groupers.

8) Conch, *Strombus gigas*, were captured by diving.

9) Nets were used in three manners: a) Gill nets were set on the bottom and around schools of jacks and tunas, b) haul seines were set around schools of jacks and tunas, and c) trammel nets were set on the bottom in likely locations for reef fish.

Figure 2.—Hauling fish traps by hand from project dory. Hydraulic net hauling equipment can be seen behind fisherman on the left of the photograph.

Catch and effort were recorded using each of these methods during each trip. Expenses recorded were: Fuel, oil, ice engine repairs, and fishing gear lost. Capital outlay was depreciated according to the following schedule: 1) Boats were depreciated over 5 years, 2) engines and fish traps depreciated over 2 years, 3) nets and other fishing gear (except traps) were depreciated over 3 years.

The success or failure of the fishing was measured by converting the catch to its cash value (fish = $1.25/pound, lobster = $2.00/pound, crabs = $1.50/pound, conch = $1.00/pound) to obtain a gross daily income. Fish prices in the Virgin Islands are stable over the year. This daily income was then converted to an annual income by multiplying it by the number of days fished by local commercial fishermen (4.5 days/week or 234 days/year). Daily expense records, repairs, and capital expenditures were deducted to obtain a net income.

Table 1.—Construction costs for experimental 15-foot dory-type boat.

Hull construction	
Marine plywood (9 sheets)	$ 450.00
1 × 4 inch lumber for gunnels (72 feet)	
1 × 2 inch framing lumber	
2 × 4 inch lumber for stronback & jig	90.00
Labor on hull construction	1,273.00
Hardware, screws, cleats, etc.	50.00
Aluminum molding for gunnel	25.00
Foam for hull (6 gallons at $20 each)	120.00
Epoxy glue (6 quarts)	100.00
Glass work	
24 feet polypropylene cloth	100.00
Epoxy resin	150.00
Fiber glass marco matte (3 yards)	12.00
Fiber glass gas tank	370.00
Labor	433.79
Paints, etc.	
Hull paint (1 gallon)	21.00
International orange	21.00
Bottom paint	36.00
Boat gear	
Anchor and line	100.00
Engine with steering controls (50 hp)	1,530.00
Fishing gear	
Fish traps ($80 each)	1,520.00
Hydraulic net hauler	2,700.00
Haul seine	2,300.00
Gill net	280.00
Trammel net	131.75
Bait nets	172.00
Electric reels ($500 each)	1,000.00
Set line	100.00
Hooks, lines, sinkers, misc.	200.00
Total	13,285.54

The average daily catch was compared with 12 years' catch records from the project's master fisherman, Joseph A. LaPlace. His catch was converted to

[1]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

1975-76 prices for purposes of the comparison. A further comparison was made to the 1974-75 results of the fisherman's catch reports (Olsen et al., 1975).

Results

The results for all fishing in the time period by each method are listed in Table 2. The location and types of effort are shown in Figure 3. We made 64 full-time fishing trips in the 18-month study period (18 percent of the number reported by commercial fishermen). Sea and wind conditions averaged 18-25 knots (estimated) and 4- to 6-foot seas. Several trips were made in 30-45 knot winds. Catch was recorded on every trip. The average trip was 9.7 hours long (19.4 man-hours).

The traditional boat was a hazard during high wind and sea conditions (estimated up to 50 knots and 12- to 14-foot seas). Any attempts at net setting led to near swampings. The dory, on the other hand, did not exhibit these limitations.

The value of the average daily catch (Table 3) was $173.29 (SD = 124.55) with daily operating expenses of $20.67 (SD = 3.55). The per fisherman gross income would have been $20,274.93. The net income ($15,394.59) is $1,703.59 greater than the average adjusted gross income ($13,691.00/man) reported by the project's master fisherman (Table 4). It is almost $13,500 higher than the average (adjusted for a 234-day fishing year) gross income reported in Olsen et al. (1975), which was $6,786/man for the local fishing community. The gross catch was around $3,750 higher than the highest catch reported by fishermen in 1974-75 or 1975-76. We do know of at least one unreported catch valued in excess of $25,000 greater than ours.

Discussion and Conclusions

The results from the first 18 months' fishing activities do offer encouragement for the local industry. Admittedly, our higher catch came, in part, from our longer fishing days (almost twice as long as fished normally by commercial fishermen) that were permitted by the absence of marketing considerations. Over 80 percent of Virgin Islands fishermen use only fish traps. Recent increases in

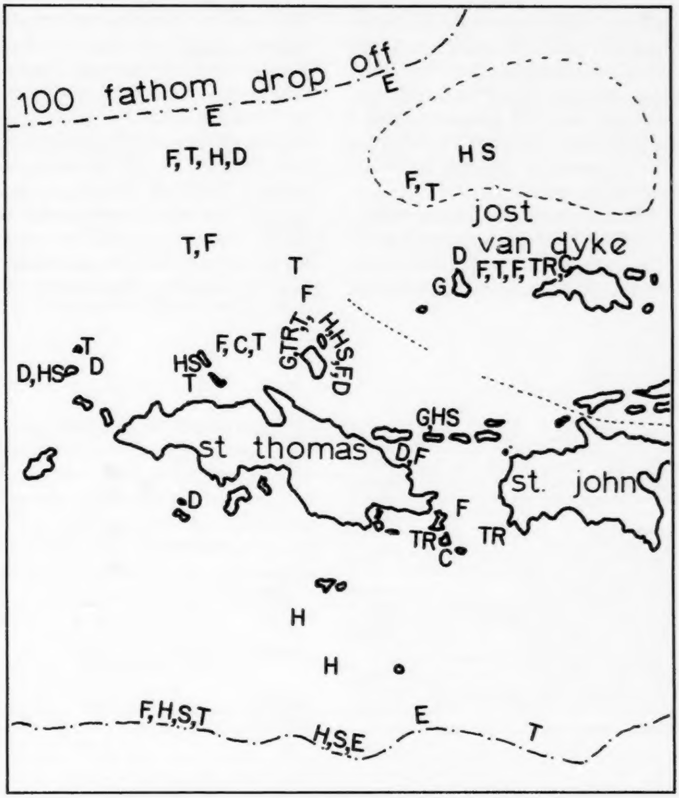

Figure 3.—This study took place on the Puerto Rico-Virgin Islands shelf. Activities included: West Indian fish traps (F), handlining (H), set lines and longlines (S), electric reel fishing (E), diving for lobsters and conch (D), crab trapping (C), trolling (T), and net fishing. Nets employed were: Gill nets (G), haul seines (HS), and trammel nets (TR).

Table 2.—Total catch and catch per unit effort (CPUE) for each of the fishing methods employed during the study period. Results are given in pounds per unit effort.

Method	Units	Total catch (lb)	Total effort	CPUE	Percent of total
Traps	set	5,154	1,016	5.07	43.2
Handline	man-hours	3,006	567	5.30	25.2
Trolling[1]	man-hours	110	74.5	1.48	0.9
Trolling[2]	man-hours	192	69	2.78	1.6
Lobsters (traps)	set	104	48	1.33	0.9
Lobsters (diving)	man-hours	274	31	8.84	2.3
Crabs	set	538	470	1.14	4.5
Electric reels	man-hours	211	35	6.03	1.8
Conch	man-hours	11	0.5	22.00	<0.1
Gill net	set	4	10	0.40	0.1
Trammel net	set	393	12	32.75	3.3
Haul seine[3]	set	1,400	4	365.0	11.7
Bait net	set	173	3	56.67	1.4
Longlines and set lines	sets	362	50	7.25	3.0
Total		11,932			100.0

[1]Trolling while running to and from fishing grounds.
[2]Trolling where fish are observed or reported.
[3]An average of 7.5 man-days are spent for setting each haul seine.

materials prices have made this fishery marginally profitable. Although 43 percent of our catch came from traps, handlining and net fishing (relatively low-overhead fisheries) may well offer a guide to future directions to be taken. This is presently occuring in Puerto Rico for the same reasons.

The experimental boat design worked exceedingly well. Boats currently in use in the Virgin Islands have evolved slowly from the carvel planked longboats of the 18th century. Construction techniques currently in use bear close resemblance to those used 200 years ago. Presently, local artisans build boats and sell them for US$2,000-3,000. Except for a small number of plywood-constructed boats in St. Thomas, most of the fishing boats in the U.S. Virgin Islands are carvel planked over natural grown and sawn frames. They are powered by outboard engines up to 175 horsepower. Because they are basically displacement hulls, fuel consumption may be as high as 12 gallons/hour (US$9.00/hour at 75 cents/gallon).

The 15-foot dory design was basically a rough-water dory. We constructed it of premium materials with commercial yacht carpenters but it is apparent that the construction cost could possibly be cut in half. Fuel consumption ranged from 1.3 to 3 gallons/hour, depending on load.

In summary, this project demonstrated that a variety of fishing techniques can be emplcyed out of a boat design that is new to the Virgin Islands. If marketing problems can be solved, longer fishing days can result in a good income at no significant increase in capital outlay.

Table 3.—Projected income from project fishing effort.

Item	Subtotal	Debit	Credit
Full time fishing year	234 days		
Number of days fished = 64	(18% of 1.5 years)		
Average daily catch	$ 173.29		
Total projected income			$40,549.86
Average daily operating expenses	$ 20.67		
Annual projected operating expenses		$4,836.78	
Boat (5-year depreciation)	$2,881.79	578.36	
Outboard engine (2-year depreciation)	1,530.00	765.00	
Nets & hauler (3-year depreciation)	3,940.65	1,313.55	
Traps (19 at $80 each)	1,520.00		
Traps (2-year depreciation)		760.00	
Repairs and maintenance	412.17		
Repair costs/day of use	6.44		
Adjusted repairs for 234-day year		1,506.99	
Total		$9,760.68	$30,789.18

Acknowledgments

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Addenda

Because 5 years have passed since these data were collected, we have recal-

Table 4.—Summary of catch statistics and value of catch of a master fisherman, 1963-74.

Year	Caught	Pounds	Price ($/lb)	Total	Number of fishermen	Gross income per fisherman (at 1975-76 prices)
1963	Lobsters	5,800	$0.70	$ 4,060.00	3	$ 7,533.12
	Net	9,800	0.35	3,430.00		
	Spearing	600	0.35	210.00		
Total		16,200		7,700.00		
1964	Lobsters	8,000	0.70	5,600.00	3	11,550.00
	Net	14,000	0.35	4,900.00		
	Traps	3,000	0.35	1,050.00		
Total		25,000		11,550.00		
1965	Lobsters	8,900	0.75	6,675.00	3	12,183.84
	Net	10,500	0.40	4,200.00		
	Traps	4,500	0.40	1,800.00		
Total		23,900		12,675.00		
1966	Lobsters	9,600	0.75	7,200.00	3	14,733.30
	Net	17,000	0.40	6,800.00		
	Traps	3,000	0.40	1,200.00		
Total		29,600		15,200.00		
1967	Lobsters	7,500	0.85	6,375.00	2	$26,312.00
	Net	20,500	0.50	10,250.00		
Total		28,000		16,625.00		
1968	Lobsters	8,600	0.90	7,740.00	2	21,100.53
	Net	20,000	0.50	10,000.00		
Total		28,600		17,740.00		
1969	Lobsters	9,000	1.00	9,000.00	3	13,500.00
	Net	18,000	0.60	10,800.00		
Total		27,000		19,800.00		
1970	Lobsters	9,800	1.00	9,800.00	3	7,575.00
	Net	2,500	0.60	1,500.00		
Total		12,300		11,300.00		
1971	Lobsters	15,000	1.00	15,000.00	3	17,916.67
	Net	19,000	0.75	14.250.00		
Total		34,000		29,250.00		
1972	Lobsters	8,300	1.50	12,450.00	3	13,366.67
	Net	18,800	0.90	16,920.00		
Total		27,100		29,370.00		
1973	Lobsters	4,000	1.75	7,000.00	2	13,375.00
	Net	15,000	1.00	15,000.00		
Total		19,000		22,000.00		
[1]1974	Lobsters	3,800	2.00	7,600.00	3	10,283.00
	Net	14,600	1.00	14,600.00		
	Traps	4,000	1.00	4,000.00		
Total		22,400		26,200.00		

[1]Began working for government.

Table 5.—Comparison of 1975 and 1978 prices and total income.

Item	Catch (lb/day)	Price ($) 1975	Price ($) 1980	Total Value ($) 1975	Total Value ($) 1980
Finfish	127.96	1.25	1.80	159.95	230.33
Lobster	2.69	2.00	3.50	5.38	9.41
Conch	0.17	1.00	3.67	0.17	0.62
Crabs	5.20	1.50	2.00	7.80	10.40
		Total/day		$173.30	$250.76
		Annual total		$40,552.20	$58,677.84

Table 6.—Projected income in 1975 and 1980 from fishing effort.

Item	1975 Subtotal	1975 Credit	1975 Debit	1980 Subtotal	1980 Credit	1980 Debit
Catch value		$40,549.86			$50,937.12	
Daily operating expenses	$ 20.27			$ 39.54		
Annual operating expenses			$4,837.47			$ 9,252.97
Boat (5-year depre.)[1]	2,281.79		578.36	4,641.15		928.23
Engine (50 hp, 2-year depre.)	1,530.00		765.00	2,052.00		1,026.00
Nets & hauler (3-year depre.)[1]	3,940.65		1,313.55			2,115.49
Traps cost/traps	80.00			125.00		
	1,520.00			2,375.00		
Total (2-year depre.)	760.00		760.00			1,187.50
Repairs and maintenance[1]			1,506.99			2,426.97
Total		$40,549.86	9,761.37		$50,937.12	16,937.16
Net profit		30,788.49			33,999.96	
Increase from 1975					3,211.47	
Annual increase from 1975					642.29	

[1]1980 prices calculated at 10 percent annual inflation.

culated some of the cost and benefit figures to see if there have been changes in the relative profitability of the experimental fishing operation. These recalculations are shown in Table 5 where the changing value of the projected catch was calculated based on changes in the value of the catch. It should be noted that fish prices in the Virgin Islands do not follow seasonal trends as the market demand is greatly in excess of the supply. The increase in fish prices between 1975 and 1980 would have provided around $10,500 in additional revenue for the fishing operation.

In Table 6 we calculated the profitability by obtaining 1980 prices for most purchased items and assuming a 10 percent annual inflationary increase for the boat construction, net fishing gear, and maintenance services. During this 5-year period, there was a 74 percent increase in operating expenses as compared with a 26 percent increase in the value of the fish landings. These results clearly indicate the decreasing profitability of this type of fishing in the Virgin Islands.

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A Corral System for Examining Pelagic Dolphin Schools

JACQUELINE G. JENNINGS, JAMES M. COE, and WALTER F. GANDY

ABSTRACT—A research platform was developed for study of schools of wild pelagic dolphins. The Porpoise School Impoundment System (PSIS) was designed to safely handle schools of up to 500 animals in a manner compatible with standard fishing procedures of tuna purse seine vessels. The PSIS attaches to the purse seine net to receive the dolphins as they are released from the net. The compartmentalized apparatus has a corral capable of holding up to 120 dolphins. The animals are maneuvered to chutes where they can be individually examined and prepared for other studies. They can be released individually or held in holding pens for release together. The PSIS was used during two cruises for coordinated studies involving capture of 1,319 dolphins. The system proved to be a safe and effective platform for open-ocean studies of wild dolphins.

Introduction

Several species of small cetaceans, primarily dolphins, are involved in the purse seine fishery for yellowfin tuna, *Thunnus albacares*, in the eastern tropical Pacific. Cetacean mortality in this fishery has been reduced from an average of 309,000 in 1971 and 1972 (Fox, 1978), to about 19,000 in 1978 (Smith[1]). This reduction in mortality is mandated by the Marine Mammal Protection Act of 1972, which also requires continual assessment of the dolphin stocks to assure that they are properly managed through regulation of the fishery.

Several assessment studies required a mechanism by which large groups of dolphins, caught by the tuna purse seiners, could be safely contained, examined, and released. These studies included examination of dolphin schools for species, age, and sex structure; investigation of school dynamics by radiotracking; and study of short-term school cohesion and integrity as well as long-term distribution and movements by tagging.

No system or technique existed for holding and handling whole dolphin schools; the species involved in the fishery have schools averaging about 500 animals. However, much information was available on the holding requirements of captive dolphins in pool enclosures. Standards for the handling and transportation of these animals have been developed by the U.S. Department of Agriculture (1979). Irvine (1970) described a lightweight, portable holding pen designed to be rapidly deployed at sea from a vessel or helicopter, but the pen was designed to hold only a single trained dolphin.

The primary design requirements were: 1) That the system be safe for dolphins and personnel alike while in the water and during deployment and retrieval from the vessel, 2) that the system be capable of holding whole dolphin schools of up to 500 animals for simultaneous release as well as for release of individual animals, and 3) that the system be compatible with the vessel's standard fishing operations.

During these operations, dolphins are released from the purse seine by a process known as "backing down," which involves the ship's manipulation of the

[1]Smith, T. D. (editor). 1979. Report of the status of porpoise stocks workshop (August 27-31, 1979, La Jolla, California). Admin. Rep. LJ-79-41, Southwest Fisheries Center, NMFS, NOAA, P.O. Box 271, La Jolla, CA 92038.

The Porpoise School Impoundment System in operation during a research cruise of the Cooperative Dedicated Vessel Program. Porpoise are being maneuvered from the tuna purse seine into the corral for examination and tagging.

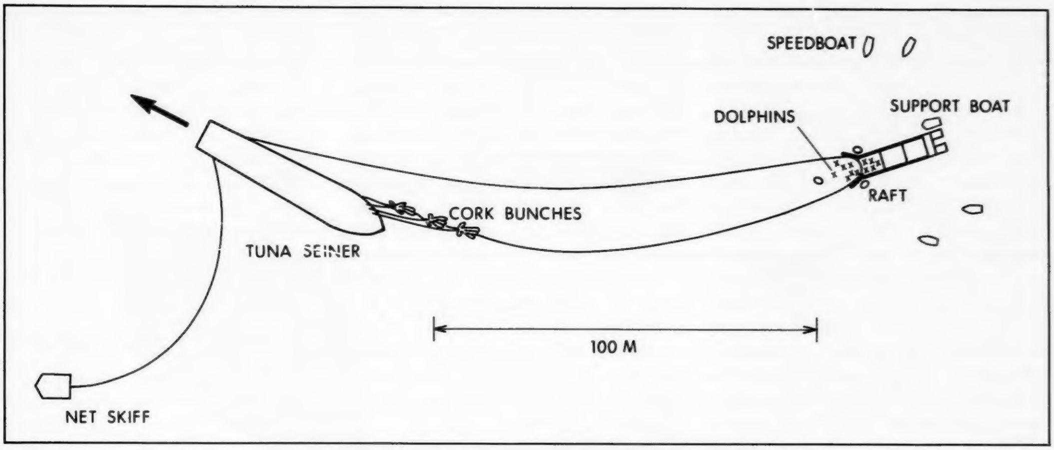

Figure 1.—The PSIS attached to the purse seine net during backdown.

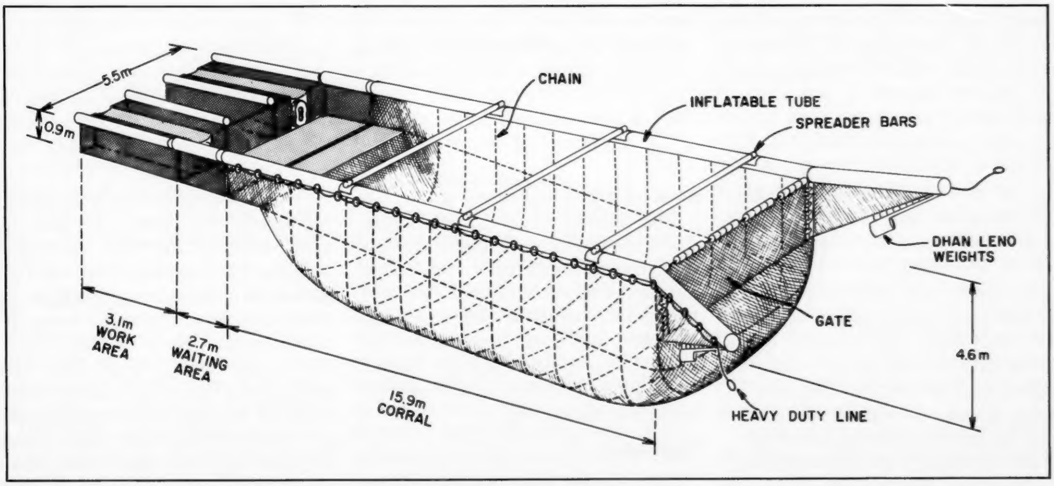

Figure 2.—The PSIS without the pens.

net into an oblong shape while the dolphins position themselves at the end farthest from the vessel. The net is then essentially pulled out from under the dolphins (Perrin, 1969; Coe and Sousa, 1972). The corral system was designed to be compatible with this release technique. It attaches to the backdown area of the net to catch the dolphins as they leave the purse seine (Fig. 1).

The research was made possible by the cooperation of the United States Tuna Foundation which provided the vessel, the *Queen Mary*, for a year to study the porpoise-tuna problem. The program was known as the Dedicated Vessel Program.

Materials and Methods

The Porpoise School Impoundment System (PSIS) (Fig. 2, 3) consists of a

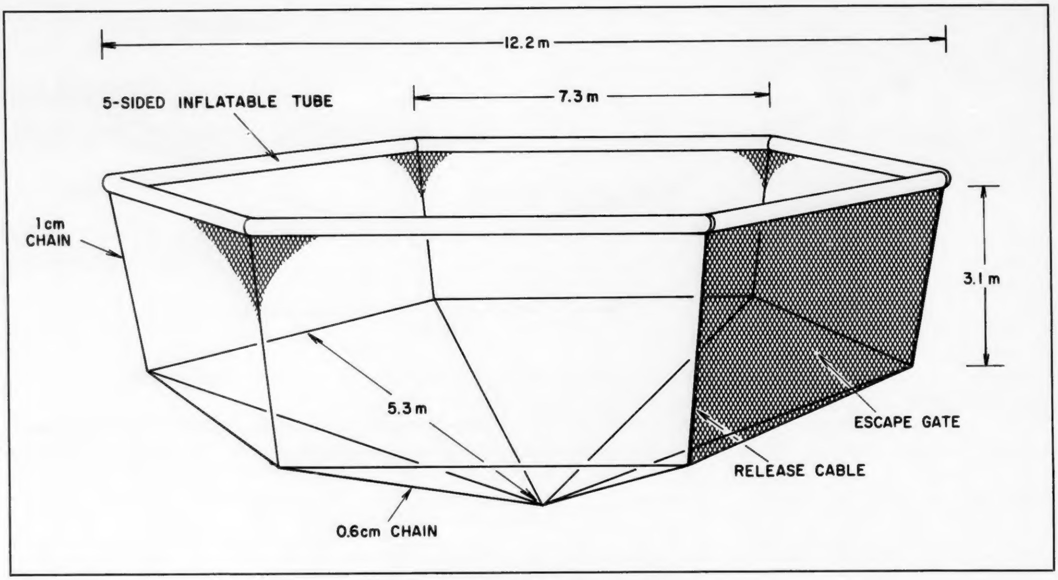

Figure 3.—A holding pen of the PSIS.

"corral" of webbing into which large portions of the school are transferred from the seine and held prior to examination; a "waiting area" of expanded aluminum mesh in which the dolphins are maneuvered individually to the chutes; two "work areas" with chutes in which the animals are measured, examined, tagged, etc.; and five "holding pens" in which groups of dolphins can be held until the school is released as a unit.

The dimensions of the corral and holding pens are based on estimated space requirements for temporarily holding individual wild dolphins. Minimum space is allowed in the corral, since the dolphins spend relatively little time in this component; allowing too much swimming room would complicate catching individual animals and prolong the operation. More space per individual is allowed in the holding pens where the dolphins could spend several hours. Both components allow for the estimated natural turning radius of 4.9 m required by an adult spotted dolphin (Pryor[2]).

The dimensions of the noncollapsible components were limited by the storage space available on the deck of the chartered medium-sized (500-ton) purse seiner and by the number of scientists the vessel could house to deploy, operate, and retrieve the PSIS. Modifications of the system were made after an initial feasibility cruise.

The Corral

The corral (Fig. 2) measures 15.9× 5.5 m, with the depth decreasing from 4.6 m at the mouth to 0.9 m at the waiting area. The shape at the surface is maintained by rigidly inflated 40.6 cm diameter nylon-reinforced polyvinyl tubes and 7.6 cm diameter aluminum spreader bars that mount into aluminum saddles on the inflatable tubes. The tubes are inserted through the sleeves formed of webbing. The weight of 0.6 cm and 1 cm galvanized chain is used to maintain the subsurface shape, especially when the corral is under tow during "backdown." Heavy-duty 2.5 cm braided nylon lines run along the base of the inflatable tubes to absorb the strain on the system when it is towed through the water. These lines run from steel rings on the purse-seine corkline to the work area. The corral weighs about 545 kg.

The corral attaches directly to the purse seine. The inflatable tubes are flared at 45° angles and have weighted net wings to prevent dolphins from escaping over the corkline and to funnel them through the gate of the corral. The gate consists of a 7.3×3.1 m panel of webbing with a corkline. The panel is lashed directly to the corkline of the purse seine, so that they sink and rise together during "backdown." After the

[2]Pryor, K. 1979. Report to the National Marine Fisheries Service on sea tests of the Porpoise Impoundment System, March 3, 1979. Dolphin Behavior Consultant, 28 East 10th Street, New York, NY 10003.

dolphins are in the corral, the lashings are cut to allow the gate to rise, blocking the opening. When the last batch of animals is transferred into the corral, the PSIS is detached from the purse seine.

A 4.6 m deep crowder net is placed in front of the gate and used to maneuver the dolphins toward the waiting area. The crowder net is hung from a floating polyurethane-foam bar and is weighted with chain. It is maneuvered with lines passed through pulleys in the waiting area.

The Waiting Area

The corral webbing attaches directly to a rectangular platform of expanded aluminum mesh buoyed by hollow, watertight support beams. Although the waiting area is neutrally buoyant, a series of 30 cm dock bumpers provides additional flotation in case any of the hollow members flood and protects the structure upon impact with the vessel during deployment and retrieval. The waiting area is about 5.5 m wide and 2.7 m long, with four walls, 0.9 m high. One wall is hinged to fold down when in use, extending the walking area by an additional 0.9 m. (When stored on the vessel, this wall is folded up to minimize space.) Standing waist deep in water, scientists can catch and lead the dolphins to the chutes. This component weighs about 454 kg.

The Work Areas

The two work areas are of construction similar to the waiting area. Each measures 3.1×1.8×0.9 m and contains a center chute with a walkway on each side. The chute of clear plastic is marked in 1 cm increments to allow for rapid measurements of dolphins. Polyurethane floats on both sides of the structure provide additional stability and safety. Interlocking automobile tires are placed between the waiting areas to allow for articulation between the components, to keep them aligned, and to prevent the aluminum structures from damaging each other. Each work area weighs about 182 kg.

The Holding Pens

Original research plans called for release of intact schools of up to 500 dolphins after examination and tagging. Five pens were designed to hold 100 dolphins each for up to 12 hours. In addition to allowing for more space per individual than allowed in the corral, the pens were designed without corners because wild pelagic dolphins do not negotiate corners. The pens are hexagonal and have sloping floors (Fig. 3). The hexagonal shape allows the pens to be efficiently clustered and monitored.

Each pen measures about 7.3 m on a side, 12.2 m in diameter, and has a center depth of 4.6 m. The subsurface shape is maintained by weighting the net with 0.6 cm and 1 cm galvanized chain. Nylon-reinforced polyvinyl inflatable tubes of 40.6 cm diameter maintain the hexagonal shape and keep the pen afloat. One side of the pen has a separate inflatable tube that is part of the release gate. The gate consists of a separate panel 7.3 ×3.1 m laced to the adjacent panels with plastic-coated steel cable strung through brass rings. When the dolphins are to be released, an aluminum spreader bar is placed across the opening, the inflatable tube is removed, and the gate is dropped by pulling the cables.

General Safety Features

All netting is of 3.2 cm stretch-mesh webbing, which has been demonstrated to minimize ensnarement of dolphin teeth and fins (Barham et al., 1977). In order to reduce abrasion of the dolphin skin, knotless webbing is used, all exposed metal edges have been filed smooth, and the expanded aluminum structures have been coated with a slick tar-based paint. All components of the system are attached so no gaps exist in which dolphins can get caught or through which sharks can enter. Heavy chains maintain the shape of the nets so that no "canopies" can form which might entrap the animals. Quick-release systems are designed into each component of the PSIS in case of emergency. The aluminum-mesh webbing provides protection from sharks. Extra flotation is provided in the event a hollow aluminum member floods, and battery-powered air pumps are available to compensate for any leaks in the inflatable tubes of the corral or holding pens. A complete above- and underwater lighting system has been developed in case operations continue into the night.

The PSIS was used during two 60-day research cruises aboard a chartered 500-ton fish carrying capacity tuna purse-seine vessel. The research was conducted in the vicinity of Clipperton Island off Mexico. The primary objective of the first cruise was to determine the feasibility of using the system to examine and tag whole schools of spotted dolphins, *Stenella attenuata*, of up to 500 animals. Capture and retention of whole schools was found to be very difficult, as portions of the school evaded capture or escaped when being transferred from the seine into the PSIS. Considerable caution was used while operational techniques were developed and environmental limitations defined. A total of 611 dolphins was captured in four net sets; 447 of these were examined for age and sex. The largest group consisted of 204 dolphins. A total of 17 dolphins was accidentally killed during the operation: 11 died in the seine or corral, 1 was killed by a shark outside the PSIS, and 5 died as a result of entanglement in the webbing. The cruise report[3] summarizes the results of the research.

Inadequate space on the vessel for storage of all five holding pens and for housing additional personnel prevented full use of the pens. One pen was used to hold 53 spotted dolphins for 7.5 hours, with no observable signs of stress and no mortality. Holding was terminated just after dark, otherwise no night work was done on either cruise.

During the second cruise, the PSIS served as a platform for a coordinated series of studies including examination for age and sex structure of schools, tagging for long-term movements, tetracycline injection for age determination, blood sampling for analysis of

[3]Coe, J. M., J. G. Jennings, C. B. Peters, and J. DeBeer. 1979. Research related to the tuna-porpoise problem: summary of research results from the second cruise of the Dedicated Vessel, 17 April to 5 June, 1978. Admin. Rep. LJ-79-6, Southwest Fisheries Center, NMFS, NOAA, P.O. Box 271, La Jolla, CA 92038.

physiological capture stress, and radio-tracking for study of short-term school cohesion. During nine sets, 872 dolphins were examined, 656 were tagged with dorsal-fin tags, 331 received tetracycline injections, 49 had blood sampled, and 6 were radio-tracked for three 2-day tracking sequences. The largest group examined consisted of 164 spotted dolphins. Thirty-six dolphins were accidentally killed: 21 died within the PSIS, 14 died in the purse seine, and 1 died after being entrapped between the seine and the corral[4].

Conclusions

The feasibility of using the PSIS as a research platform for study of wild pelagic dolphin has been demonstrated. One thousand three hundred nineteen (1,319) dolphins were successfully examined, with very low mortality. Although the system was never used to its design capacity of 500 animals, handling schools of this size should be possible if all conditions are ideal.

Major limitations on the use of the system include environmental conditions, species composition of the school, available daylight, and number of people available to operate the PSIS. To be safe, sea state should not exceed Beaufort 3 and winds should not exceed 12-14 knots. Special attention should be paid to impending weather. Spotted dolphins, *S. attenuata*, are generally calmer animals and are considerably easier to handle than are spinner dolphins, *S. longirostris*. The more active spinners require additional space and close monitoring because there is a greater risk of mortality or injury. Since it is advisable to conduct all activities in daylight, the time of day the school is found and operations can commence is critical. Generally, 5-6 hours are required from time of deployment to retrieval of the PSIS. Operation of the system without the holding pens requires 8-10 persons. A detailed operations manual[5] is being prepared.

The limits of the system are defined. The corral can hold a maximum of 120 dolphins, with no more than 50 spinner dolphins if the species composition of the school is mixed. While the largest school contained 204 animals, processing larger schools should be possible by repeatedly placing groups of about 120 dolphins in the corral during multiple backdowns. The maximum holding capacity for each pen is 75-100 dolphins.

Simultaneous release of animals from more than one pen would be difficult. The pens tend to collapse when being towed, and since the backdown procedure requires pulling the net through the water, a pen of dolphins would have to be set adrift with attendant personnel before backdown. The pens therefore could become widely separated. Additional personnel and boats would be required to monitor the pens and release all groups simultaneously. The dolphins would probably regroup after release.

[4]Powers, J. E., R. W. Butler, J. G. Jennings, R. McLain, C. B. Peters, and J. DeBeer. 1979. Summary of research results from the fourth cruise of the Dedicated Vessel, 12 September to 31 October. Admin. Rep. LJ-79-14, Southwest Fisheries Center, NMFS, NOAA, P.O. Box 271, La Jolla, CA 92038.

[5]Coe, J. M., J. G. Jennings, R. W. Butler, and W. E. Stuntz. In press. An operations manual for the Porpoise School Impoundment System (PSIS). NOAA Tech. Memo., Southwest Fisheries Center, NMFS, NOAA, P.O. Box 271, La Jolla, CA 92038.

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Gains Made in Protecting World's Whale Stocks

Progress was made in protecting the world's whales at the annual meeting of the International Whaling Commission (IWC) in Brighton, England, in July, the National Oceanic and Atmospheric Administration reports.

The Commission imposed a zero quota for the hunting of sperm whales in all areas except the western North Pacific. There is no quota for the area unless the Commission adopts one at its special meeting next March. Sperm whaling also had been permitted in the southern hemisphere and the North Atlantic.

The Commission extended its ban on the use of nonexplosive grenade harpoons to apply to the commercial harvesting of minke whales. These so-called "cold" grenades, which are considered inhumane, were prohibited last year for all commercial whaling operations except minke whaling. The extended ban takes effect in 1983. The Commission also said it recognized the need to upgrade its management procedures, and will work toward accomplishing that goal by next year.

The U.S. delegation had pressed for an immediate moratorium on all commercial whaling and also sought to strengthen management procedures governing commercial whaling, develop procedures to manage subsistence whaling by aboriginal people, and ban the use of cold harpoon grenades to kill whales.

The U.S. position on these issues is developed by a committee from NOAA, the State Department, Interior Department, the Marine Mammal Commission, members of Congress and groups representing wildlife management, animal protection, and native peoples.

The IWC was formed in 1946 to review and establish conservation measures to protect the world's whale stocks.

John Byrne Is New NOAA Administrator

John V. Byrne was sworn in on 24 July as Administrator of the Commerce Department's National Oceanic and Atmospheric Administration (NOAA). Commerce Secretary Malcolm Baldrige officiated at the ceremony.

Byrne previously was vice president for research and graduate studies at Oregon State University, Corvallis. He had held various positions in research and oceanography at the university since 1960.

He was an Associate Professor in 1960-65; Professor and Chairman, Department of Oceanography in 1968-72; Dean, School of Oceanography in 1972-76; Acting Director, Marine Science Center in 1972-77; Dean of Research (Acting) in 1976-77; Dean of Research in 1977-80; Dean of the Graduate School (Acting) in 1979-80; and Vice President for Research and Graduate Studies since 1980.

John V. Byrne

Byrne was Program Director for Physical Oceanography, National Science Foundation in 1966-67. In 1966-68 he

An Ocean Energy Role for NOAA

The Commerce Department is clearing the way for a multibillion dollar U.S. export activity, based on the technology of harnessing energy from the oceans. Commerce Secretary Malcolm Baldrige said the department has prepared a "one-stop" licensing system for commercial development of ocean thermal energy conversion (OTEC).

Baldrige said the regulations remove any legal or international barriers for such development. They will help U.S. firms comply with both domestic and international laws. They were published in the *Federal Register* on 31 July.

The licensing program is being conducted by the department's National Oceanic and Atmospheric Administration. NOAA Administrator John V. Byrne pointed out that more than 60 countries, many of them poorer nations dependent on imported oil, have ready access to thermal resources. "If U.S. private industry reaches even a small percentage of that market, OTEC sales should total several billion dollars a year during the next 30 years," he said.

Ocean thermal energy conversion is expected to compete effectively in world energy markets. It taps the solar energy stored in warm surface waters of oceans. Most of this power can be transmitted to shore for use by electric utilities. OTEC plants also use the electricity generated to produce other energy-intensive products such as ammonia or aluminum.

The system uses a fluid such as ammonia that is able to boil and condense over a small temperature range. As the surface water's warmth is transferred to the fluid in a large heat exchanger, the fluid evaporates into a gas that runs a low pressure turbine. Cold bottom water drawn from the ocean's depths is used to condense the vapor back into a liquid. The plants can be located either at sea or on adjacent land sites.

was a geologist with the U.S. Geological Survey.

He has been a member of many scientific and professional societies including: American Society for Oceanography; Marine Technology Society; Society of Economic Paleontologists and Mineralogists; American Association of Petroleum Geologists; and the University Corporation for Atmospheric Research. He is the author of many articles and papers on geology and oceanography.

Byrne was graduated from Hamilton College (B.A., 1951); Columbia College (M.A., 1953); and the University of Southern California (Ph.D., 1957).

Byrne is married, has four children, and resides in Corvallis, Oreg. He was born in Hempsted, N.Y., on 9 May 1928.

The Role of Aluminum in Fish

Aluminum (Al) is not considered to be an essential trace metal in fish. Nevertheless, when research diets are compounded for trout or salmon, the trace metal pack used in these diets invariably contains aluminum, usually to bring the final diet to about 10 ppm aluminum. The basis for inclusion of aluminum and other trace metals (e.g., copper, manganese, or cobalt) in fish diets was trace metal analysis of either whole fish carcasses or fish eggs. Simply put, it was believed that trace metals found in wild populations of fish indicate that these metals were required for good fish nutrition.

In some preliminary studies being conducted by the NMFS Northwest and Alaska Fisheries Center's Utilization Research Division of trace metal bioavailability and requirements of salmonids during their life cycles, some unusual changes were observed in whole body aluminum concentrations. Unfertilized trout eggs were found to contain 49 ppm aluminum. As the fish hatched from the egg, the combined fish plus yolk sac contained 77 ppm aluminum. When the yolk sac disappeared, the fish contained only 6-10 ppm aluminum. As the fish continued to grow, tripling in weight, the whole body concentration of aluminum declined to <4 ppm. During this growth development period, calcium (Ca) continued to increase as expected since bone was forming in the fish (1,400 ppm calcium in the ova to 22,000 ppm in the 1.5 g fish).

So far no work has been reported on the growth and survivability of fish fed reduced aluminum diets. However, the marked decline in aluminum as the fish grows strongly suggests that this metal may play a role in the early development of the fish or in the reproductive process. The apparent decline of aluminum during this early stage of fish growth may be related to the rapid tissue and bone formation. The high concentration of aluminum in the yolk sac might be associated with membrane architecture, egg fertility, or survivability. While no feeding studies utilizing aluminum-deficient diets are planned, the levels of aluminum in fish tissue, at various life stages, will be monitored. If indeed aluminum is essential in salmonid nutrition, the implication of this finding will play a major role in proper formulation of hatchery diets and concomitant salmonid aquaculture.

John C. Wekell

Electron Microscopy to Examine Structural Changes in Fish Muscle

The development of tough, dry texture during frozen storage of certain species of fish has been attributed to changes within their myofibrillar proteins. Electron microscopy is just now becoming a useful food research tool to follow these changes. Interestingly, the functional properties of fish muscle that are so important in fabricating foods are directly related to the changes in these myofibrillar proteins.

In cooperation with Joyce Hawkes, of the NMFS Northwest and Alaska Fisheries Center, the Center's Utilization Research Division has been using the electron microscope to determine the role of the ultrastructural changes occurring in pollock muscle during frozen storage on the functional properties of fish muscle. Electron micrographs of fresh frozen pollock revealed that the muscle fibers are very similar to striated muscle of any meat where individual fibers are made up of myofibrils, each consisting of parallel actin and myosin filaments.

After 2 months of frozen storage, electron micrographs of fillets that still retained their functional properties revealed that they had undergone very little ultrastructural change. However, the myofibrils had been broken into much shorter lengths with complete breakdown of the Z-band material in the fillets exhibiting no functional properties. This alteration of the actin filaments appears to be much more important than the side-to-side aggregation of the myofibrils that has normally been thought to occur during frozen storage. Thus, electron microscopy will serve as a useful tool as we develop new processes and chemical treatments to stabilize and maintain the desirable functional and quality properties of fish muscle.

Jerry K. Babbitt

Ludwig Directs NOAA's Environment Research Lab

George H. Ludwig has been named Director of the Environmental Research Laboratories of the Commerce Department's National Oceanic and Atmospheric Administration (NOAA). He has served as senior scientist of the Boulder, Colo., research organization since November 1980.

Ludwig has been with NOAA since September 1972, when he became Director of systems integration in NOAA's National Earth Satellite Service (NESS). He later became Acting Technical Director of NESS, responsible for all technical activities including operation of the geostationary and polar-orbiting satellites, data acquisition, data processing and distribution, and satellite applications research.

Prior to joining NOAA, Ludwig was employed by the National Aeronautics and Space Administration, and was the Associate Director for data operations at the Goddard Space Flight Center.

The Tuna Fishery of the Republic of South Africa

The Republic of South Africa has the continent's largest and most modern fishing industry. Resource problems, partly caused by extensive foreign fishing, have caused severe economic problems in the industry. The tuna fishery plays a minor role in that industry, but unlike most other fisheries it has recently undergone a dramatic expansion.

Catch

South Africa's 1979 total tuna catch of 7,500 metric tons (t) represents only slightly more than 1 percent of South Africa's average annual fisheries catch of approximately 620,000 t. The country's small tuna fishery, however, is undergoing a rapid expansion. The catch total of 7,500 t in 1979 is a 1,350 percent increase over the 1978 catch of 500 t. Preliminary reports for 1980 suggested that the catch would be below that of 1979.

Industry Expansion

The South African tuna industry began to expand over the last half of the 1970's. The expansion became dramatic in 1979, as prices for tuna rose and yellowfin tuna hit $2,000 per ton in April 1979, well over the $1,600 per ton which the South Africans consider to be the lowest price at which tuna fishing was viable.

Trawlers and purse seiners, idled by closures in other fisheries, as well as rock lobster vessels idled by falling prices for that species, were deployed in the tuna fishery. The fishermen at first chose pole-and-line fishing because the gear was inexpensive and no costly vessel modifications had to be made. The vessels could thus easily be reconverted for use in their original fishery. Some vessels specifically designed for tuna fishing, however, were added to the fleet in 1980.

The South Africans have dramatically increased their total tuna catch since 1977. The total annual tuna catch surpassed 200 t only in 1977, when it reached 285 t. The catch doubled in 1978, reaching over 500 t. So many new entrants began fishing in 1979 that the catch increased a phenomenal 1,350 percent to almost 7,500 t (Table 1).

The species composition of the catch has changed as the South Africans have developed the fishery. The most important species caught was albacore until 1977. Albacore traditionally made up more than one-half of the total tuna catch, while skipjack and yellowfin tuna alternated as a distant second and third. The expansion of the industry has come mostly in yellowfin tuna, which jumped from a negligible catch of 6 t in 1976 to over 280 t in 1978 (Table 1). The 1978 yellowfin tuna total represented over 50 percent of that year's total tuna catch. Catch data by species is not available for 1979, but the NMFS Division of Foreign Fisheries Analysis believes that much of the increased catch was yellowfin tuna.

Table 1.—South Africa's tuna catch in metric tons, by year and species[1].

Species	Catch (t) 1975	1976	1977	1978	1979
Atlantic bonito	5	—	4	16	NA[2]
Skipjack	1	—	40	90	NA
Albacore	154	35	74	126	NA
Yellowfin	18	6	167	281	NA
Total	178	41	285	513	7,483

[1]Source: FAO "Yearbook of Fishery Statistics," 1978, and preliminary 1979 figures.
[2]NA = Not available.

South African fishermen are increasing their yellowfin catch by fishing in the region 150-200 miles south of Cape Agulhas, the southernmost point of South Africa. Large stocks of yellowfin tuna migrate to this area both in the summer and in the winter, and have traditionally been fished by Taiwanese and Japanese fishermen using longliners. South Africans first started fishing south of Cape Agulhas in 1977, but only since 1979 have they had large enough vessels and modern enough equipment to fish the winter schools. Approximately 40 vessels from South Africa, Japan, and Taiwan fished for tuna in this region in 1979 and the total tuna catch was between 1,500 and 2,000 t per month.

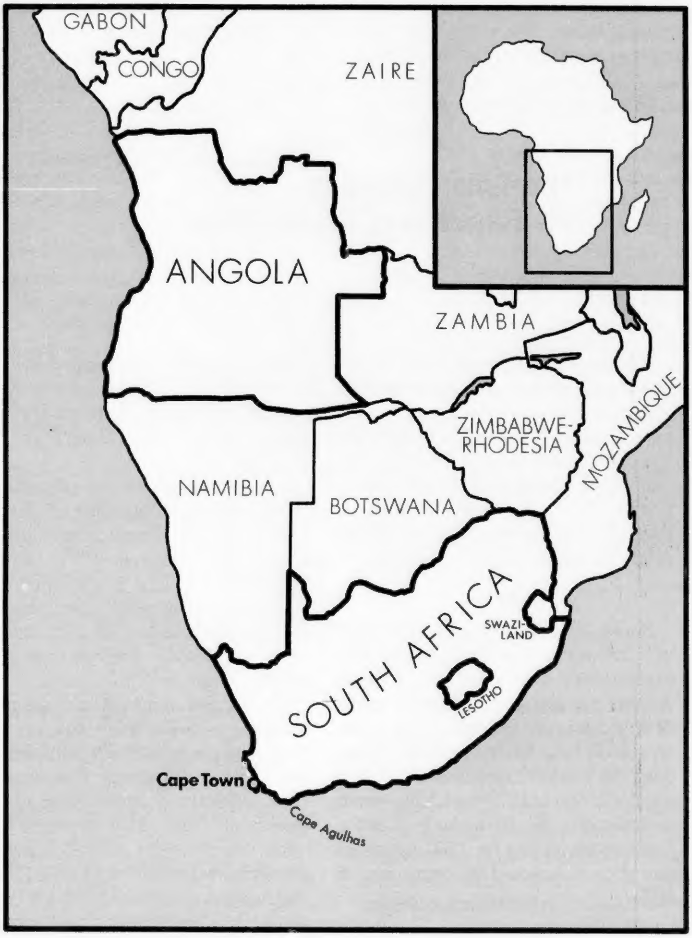
Investments

South Africans have made considerable investments in the tuna fishery. In addition to the conversion of already existing vessels for use as tuna pole-and-line vessels, several new vessels have been purchased from abroad and others built in South Africa. Additional freezing equipment has been installed on the existing vessels. Processing companies have constructed ice plants, blast freezers, and cold stores on shore to support the expanding fishery. A major South African fishing publication estimated in October 1979 that approximately $2.6 million had been invested in the tuna industry over the previous 6 months.

Note: Unless otherwise credited, material in this section is from either the Foreign Fishery Information Releases (FFIR) compiled by Sunee C. Sonu, Foreign Reporting Branch, Fishery Development Division, Southwest Region, National Marine Fisheries Service, NOAA, Terminal Island, CA 90731, or the International Fishery Releases (IFR) or Language Services Biweekly (LSB) reports produced by the Office of International Fisheries Affairs, National Marine Fisheries Service, NOAA, Washington, DC 20235.

Continued expansion of the South African tuna industry has implications for the country's international fishery relations. Taiwan and Japan, along with Israel, are the only countries to have signed fishing agreements with South Africa since it implemented its 200-mile Exclusive Economic Zone (EEZ) on 1 November 1977. The Taiwanese agreement, unlike the agreement with Japan and Israel, covers only tuna. Two hundred Taiwanese and Japanese vessels, many of which fished for tuna, were reported in 1979 to be fishing in South Africa's waters, but in early 1980 they were reported to be pulling out of their bases in Cape Town and other South African ports because of high fuel costs.

If the South African tuna industry continues to expand and prosper, South African fishermen can be expected to pressure their government not to renew Taiwanese and Japanese fishing licenses. The only factor which could offset this pressure is the fact that the South African Government signs fishery agreements in exchange for trade considerations in areas other than fisheries, and these considerations might be more important to the Government than the plans of South African fishermen to expand their activities.



Prospects

Further expansion of the industry seems likely, unless 1979 proves to only represent an unusually high occurrence of tuna off South Africa. Certainly South Africa could rapidly increase its catch if stocks could sustain a significantly increased effort. South Africa's large and modern fishing industry has already demonstrated its ability to expand its activities over a short period of time, and has the capacity for considerable further expansion. In addition, South African fishing industry sources report that stocks of bigeye, albacore, and bluefin tuna are to be found in the waters west of the areas where yellowfin tuna is now being caught. These stocks, combined with those now being abandoned by the Taiwanese and Japanese fishermen, may enable South African tuna fishermen to continue the expansion of the country's tuna fishery. (Source: IFR-80/171.)

Finland Imports and Exports More Fish

The quantity of fishery imports by Finland increased by 10 percent from 239,000 metric tons (t) in 1979 to 263,000 t in 1980. The value of these imports increased by 21 percent from US$91 million in 1979 to US$111 million in 1980. Imports of fish offal and fish meal increased by 9,000 t and 12,000 t, respectively.

Meanwhile, Finland's exports of fishery products increased by more than 40 percent from 2,688 t in 1979 to 4,020 t in 1980, while their value increased by more than 150 percent from US$2.7 million in 1979 to US$6.7 million in 1980. This change was caused mainly by an increase in the exports of canned fishery products (mostly sardines) from 271 t to 881 t. Fresh fish exports more than doubled to 660 t. Eastern European nations were the largest importers of Finnish canned products. (Source: IFR-81/138.)

The Tuna Fishery of Angola

Angola has one of Africa's most important tuna fisheries. The fishery has recovered from the economic dislocations of the civil disturbances which followed independence from Portugal in 1975 much more quickly than the other sectors of the fishing industry. It is now becoming an increasingly important part of the country's fishing industry.

Catch

Angola's total fisheries catch dropped precipitously after independence, from a high of 470,000 metric tons (t) in 1973 to a low of 74,000 t in 1976 and had recovered to only 118,000 t in 1978. The tuna fishery, on the other hand, reached its low of 1,700 t in 1975, recovered quickly, and even expanded, so that the 1977 tuna catch of 8,600 t exceeded the preindependence record of 7,800 t reported in 1974 (Table 1). Thus, the Angolan tuna fishery rose from only 2 percent of the total fisheries catch in 1974 to 6 percent in 1978. No data is available for 1979 and 1980, but unconfirmed reports indicate that catches in October 1980 were very good.

Vessels

Although little information on Angola is available, it seems that the resilience of the tuna fishery is related to the fact that the tuna fleet was not as adversely affected by the 1975-76 civil disturbances as was the rest of the fishing fleet. Many of Angola's other fishing vessels were either destroyed in the 1975-76 disturbances or moved to other countries when the Portuguese left in 1975. ICCAT statistics indicate, however, that 45 Angolan tuna vessels were fishing off the country's coast in 1978, only two less than the number of vessels in the fleet during 1970 (data for the years immediately preceeding the 1975-76 disturbances are not available). Thus, either the tuna fleet was not affected by the fighting or Angola has succeeded in replacing its tuna vessels.

Foreign Fishing

The only foreign countries currently known to be catching tuna in Angolan waters are Cape Verde and Spain. An agreement with Cape Verde allows three of that country's tuna vessels to fish off Angola from October to May, when there is little tuna in Cape Verde's waters. The terms of the agreement with Cape Verde are not known, but it is believed that most of the catch is landed in Angolan ports.

Spain, whose fishermen operated off Angola before independence, continued to fish off Angola after independence without an agreement. Some of the Spanish vessels were seized by Angolan authorities, and Spain finally concluded a fisheries agreement with Angola in June 1980. The 3-year agreement grants Spain an allocation of 12,000 t of tuna, 12,000 t of hake, and 18,000 t of shellfish off Angola, in exchange for license fees and technical assistance. The Spanish reported good 1980 catches.

Angola licensed Congo vessels to catch tuna in 1979. Apparently the Congo did not renew the licenses in 1980 and Angola seized the *Anzika*, an Italian-built vessel with a carrying capacity of 1,200 t. Angola confiscated the catch of about 100 t and the net.

Prospects

Prospects for the Angolan tuna fishery are hard to determine. Although statistics indicate continued growth for the fishery, the dearth of information makes it difficult to determine what the future of the industry will be. At present, it can be said that the Angolan tuna fishery continues to be one of the most important in Africa, as well as an increasingly important sector of the country's fishing industry. (Source: IFR-80/178.)

Table 1.—Angola's catch of tuna and tuna-like species, 1973-78.

	Catch (t)					
Species	1973	1974	1975	1976	1977	1978
Skipjack tuna	1,443	3,474	652	1,514	4,036	3,501
Yellowfin tuna	603	839	55	1,005	2,085	2,296
Little tuna	970	1,287	449	10	1,326	826
Frigate and bullet tuna	1,119	1,536	535	27	198	357
Atlantic bonito	499	351	38	831	938	531
W. African Spanish mackerel	—	348	—	—	20	81
Total	4,634	7,835	1,729	3,387	8,603	7,592

Source: FAO "Yearbook of Fishery Statistics," 1978 and ICCAT "Statistical Bulletin," 1978.

JAPAN AND FRANCE EXTEND FISH PACT

Japan and France have extended their earlier fisheries agreement on 3 July 1981 for another 13 months. The previous 15-month pact would have ended on 19 July 1981.

Thus, Japanese tuna longliners and skipjack pole-and-line vessels will be allowed to operate inside the 200-mile zone in five French overseas territories: New Caledonia, French Polynesia, Wallis Futuna, Tromelin and Glovieuses, and Clipperton. The maximum catch quota given to the Japanese for the duration of the agreement was set at 12,900 t; 490 Japanese vessels will be allowed to fish and their owners will have to pay a fishing fee of US$541,000. (Source: IFR-81/138.)

The Tuna Fishery of Ghana

The fishing industry of Ghana is only Africa's eighth largest, but its tuna fishery is one of Africa's most important. Ghana's total 1978 fisheries catch was 260,000 metric tons (t), well behind Africa's two leading fishing nations, South Africa (628,000 t) and Nigeria (519,000 t). Ghanaian fishermen caught a record 20,900 t of tuna and tuna-like species in 1977, more than any other African country. Tuna seiners under construction in Norway and Italy will enable Ghana to significantly increase its tuna catch. The new vessels will also allow Ghana to shift fishing effort to the more valuable tuna species such as yellowfin and skipjack tuna.

Fishermen

Ghana has both an artisanal and a commercial tuna fishery. Because of the importance of artisanal fishing, the Ghanaian tuna fishery is currently one of the least modern in Africa. Ghana's artisanal fishermen bring in approximately two-thirds of the country's total tuna catch. They generally fish within a few kilometers of the coast, using pirogues (small wooden canoes about 6-8 m long) and nets. These fishermen are thus dependent on finding tuna close to the coast. When climatic conditions affect the tuna's migratory patterns so they do not appear in such large numbers close to the coast, as apparently occurred in 1978, the artisanal catch can drop precipitously.

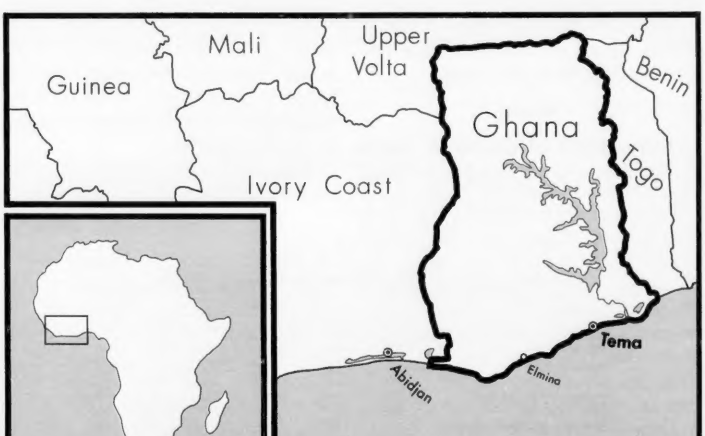
Fishing Fleet

Ghana's small commercial fishing fleet is dominated by two companies, Mankoadze Fisheries Ltd. and the State Fishing Corporation (SFC). Mankoadze, Ghana's largest fishing company, has three joint tuna ventures: One with a U.S. tuna company, one with a Japanese tuna company, and the third in conjunction with both companies.

Mankoadze's tuna fleet consists of pole-and-line vessels, tuna purse seiners, and refrigerated transports, and is currently being expanded by the addition of eight more purse seiners under construction in Norway which reportedly have carrying capacities of 800 t each. The first of these seiners[1], the *Donna H*, was delivered to Mankoadze in August 1980. The *Donna H* landed its first load of tuna, reportedly 220 t, during October and the owners were pleased with the vessel's operation. The new crew was then still being trained and it took over 12 days to unload the catch. The second Norwegian seiner, the *Stendel*, was delivered in December. Each succeeding vessel was scheduled to be delivered in 4-month intervals with all seven scheduled to be delivered before the end of 1981.

SFC, a state-owned company, has only a few tuna vessels (exact number unknown), but its tuna catching capacity was expected to be greatly expanded by the purchase of two 80 m tuna seiners with carrying capacities of 1,200 t which were constructed by the Italian shipyard Societá Esercizio Cantieri. The first vessel, the *Bonsa*, was delivered in 1980 but had not then been deployed in the fishery. The second vessel, the *Via Reggio*, was also to be launched in late 1980. The Italian Government helped finance this and other projects in West Africa to assist Italian shipyards. The contract with the Italians stipulated that the design of the vessels had to conform to Lloyd's standards, so there were many expensive, sophisticated backup systems. This made the vessels expensive and also made key areas of the vessels,

[1]It is believed that these vessels are multipurpose vessels which can be employed in other fisheries.



such as the engine room, crowded and difficult to work in. The contract also required the Ghanaians to hire a knowledgeable firm to operate the vessels[2]. The Ghanaians were negotiating with a U.S. tuna company.

Ghana may have difficulties crewing such a large number of new vessels. The masters and more highly skilled positions in West African tuna seiners are frequently filled by Europeans. Foreign companies which manage West African fleets often like to employ fishermen from countries other than the country where the vessel is based. They find that the local fishermen do not like long voyages and often object to returning to sea with only a short port call. Oddly enough, crew members are often from Mali, Upper Volta, and other landlocked, but economically depressed countries. There also tend to be a lot of Malagasy crew members.

Table 1.—Ghana's catch of tuna and tuna-like species in metric tons, 1974-1978[1].

Species	Catch (t) 1974	1975	1976	1977	1978
Little tuna	66	138	76	54	6,049
Skipjack tuna	701	5,937	8,167	4,661	2,866
Frigate and bullet tuna	6,295	5,997	4,284	14,605	1,287
West African Spanish mackerel	3,513	598	555	740	807
Yellowfin tuna	342	567	451	649	485
Bigeye tuna	–	280	664	230	185
Atlantic bonito	33	20	–	9	9
Total	10,950	13,537	14,197	20,948	11,688

[1]Source: FAO "Yearbook of Fishery Statistics," 1978.

Table 2.—Ghana's tuna shipments to the United States, product weight, 1977-1979[1].

Item	Quantity (t) 1977	1978	1979	Value (US $1,000) 1977	1978	1979
Frozen						
Albacore	2.6	59.2	–	1.2	26.1	–
Skipjack tuna	3,131.5	6,816.9	3,405.5	759.2	4,442.5	1,487.5
Yellowfin tuna	232.1	367.0	182.6	88.2	131.0	76.6
Other	426.0	745.9	146.5	140.9	564.2	123.7
Canned	–	76.2	89.5	–	182.0	246.8
Total[2]	3,792.2	8,065.2	3,824.0	989.4	5,345.8	1,934.6

[1]Source: U.S. Department of Commerce, Bureau of the Census.
[2]Totals may not agree due to rounding.

Port

Tema, the main port of the Ghanaian fishing industry, is also the center of the country's tuna fishery. Tema's existing port, which was opened in 1960, includes 12 berths, one oil berth, a drydock, and a slipway. Ghana's two canneries are also located in Tema, and both primarily process tuna. There are several cold stores in the city which are used to hold frozen tuna for transshipment to other countries. Tema is Africa's third largest tuna transshipment center, after Abidjan and Dakar, and large amounts of frozen tuna caught by foreign fishermen pass through Tema each year.

Catch

Ghana's tuna catch totaled 11,700 t in 1978 and consisted mainly of little, skipjack, and frigate tunas.[3] Catches of these species have fluctuated widely since 1976 (Table 1). Frigate and bullet tunas, traditionally the most important species caught, are taken mainly by artisanal fishermen. The catch of these species, however, was severely affected by changing migratory patterns in 1978. It is not known why the catch of little tuna increased so sharply in 1978. The increase could represent a change in reporting practices or possibly the incorrect identification of species.[4] No data is available for 1979 and 1980. Unconfirmed reports suggest, however, that catches have been below average in both years.

Processing

The tuna processing industry in Ghana is small, consisting of only two canneries. Both canneries, located in Tema, are currently underutilized. One of the canneries is associated with a U.S. company which is extremely pleased with the quality of the canned product. A project to open a third cannery at Elmina, in central Ghana, was shelved by the Ghanaian Government because the existing canneries were not being fully utilized. The Government did take steps to improve the position of the canning industry by changing the country's foreign fishery regulations.

Exports

No statistical data is available on Ghanaian exports. The NMFS Division of Foreign Fisheries Analysis believes, however, that most of the tuna canned in Ghana is exported, primarily to the European Economic Community countries. Frozen tuna is also exported or transshipped, although no Ghanaian data is available on these shipments. United States import data suggests that a large part of the Ghanaian skipjack catch is shipped frozen to the United States, although statistical analysis is complicated by the possibility that some tuna caught by foreign vessels and processed in Ghana may be included in the U.S. import data (Table 2).

Foreign Fishing

Ghanaian Minister of Agriculture E. K. Andah has sought to change Ghanaian fishing regulations. Foreign fishermen were formerly requested to land 20

[2]The SFC has a fleet of stern trawlers, and the Italians were concerned about the number of vessels currently idled in Tema in need of repair.

[3]Frigate mackerel, *Auxis thazard*, and bullet mackerel, *A. rochei*, are sometimes referred to as "tunas." In this report, the FAO system has been followed, which groups the two species and West African Spanish mackerel, *Scomberomorus tritor*, with the tunas.

[4]U.S. tuna imports from Ghana increased sharply in 1978, but primarily because of increased skipjack imports, not little tuna.

percent of their catch in Ghana, 10 percent as a fishing fee and 10 percent for sale to Ghanaian canneries. Government officials were negotiating new arrangements with foreign fishermen. The Government sought to impose a flat fee of $150 per GRT, but would like the fishermen to continue selling at least 10 percent of this catch to local canneries. The Government also planned to charge foreign reefer and longline vessels $2,000 per port call. These new regulations were expected to go into effect on 1 January 1981.

Foreign fishermen landed or transshipped 30,000 t of tuna in Ghana during 1977, the last year for which statistics are available. This level seems likely to decline in the future, if it has not already begun to do so. Ghana's new fisheries law, the Fisheries Decree of 1979, limits foreign fishing in Ghanaian waters and encourages foreign fishermen to form joint ventures with majority Ghanaian ownership. It is unclear what effect the decree has had on foreign tuna fishing activities thus far, as there were already several joint tuna ventures. It is possible, however, that the new regulations could lead to the eventual phasing out of foreign fishing in Ghanaian waters over the course of the next several years.

Prospects

The NMFS Division of Foreign Fisheries Analysis believes that the Ghanaian tuna catch should show substantial increases by 1981 and 1982. The commercial fishery will surpass the artisanal fishery in importance as the new Norwegian and Italian seiners are added to the fleet. These new vessels will allow the Ghanaian fishermen to direct a substantially increased effort on yellowfin and skipjack tunas and become one of West Africa's leading tuna fishing nations. (Source: IFR-80/181.)

RAFTS TESTED TO ATTRACT TUNAS

An experiment aiming to attract tuna schools with artificial drifting rafts by Japan Marine Resources Research Center has reportedly achieved initial success. Four rafts, two made with specially designed metal tubes and two with mosho bamboo, were placed in the South Pacific last November, and fish began to congregate in February. So far, the Center-chartered purse seiner *Fukuichi Maru* (499 gross tons) caught 35 metric tons (t) in one setting, and another purse seiner, the *Nippon Maru* (999 gross tons), 123 t in three settings in the vicinity of the rafts.

The strength of the anchor line currently in use is said to limit the depth of placement of the raft to about 2,000 m, but the manufacturer reportedly claims that the depth of placement could be doubled with the use of a thicker line. The Center is reported to be planning to continue the experiment for the rest of the year.

Locations of the rafts are as follows: No. 1 raft (metal): lat. 2°S, long. 156°24′E, water depth 1,680 m; No. 2 raft (metal): lat. 2°S, long. 156°11′E, water depth 1,760 m; No. 3 raft (mosho bamboo): lat. 1°50′S, long. 156°12′E, water depth 1,700 m; No. 4 raft (mosho bamboo): lat. 1°50′S, long. 156°20′E, water depth 1,700 m. Announced catches are as follows: *Nippon Maru*, Feb. 22 (10 t), Feb. 24 (24 t), Feb. 26 (75 t); *Fukuichi Maru*, Feb. 4 (35 t). (Source: FFIR 81-5.)

Meanwhile, technicians of the Inter-American Commission on Tropical Tuna plan to test a system based on balsa rafts for attracting tuna. The procedure is an adaptation of one the Philippine fishermen have used for many years with good results.

The rafts are made of wood and polyurethane and measure 3.6 m long by 1.2 m wide and 30 cm thick. From the bottom and sides hang old nets which, it seems, attract tuna with their undulations. On top of the raft, on a tripod, are position lights and a radar globe and reflector to prevent collisions with boats.

According to Philippine fishermen, the tuna congregate around floating objects of this type and are therefore much easier to catch. Commission technicians want to use this method to permit the capture of tuna without affecting the dolphins which usually accompany the schools.

According to the plan, five rafts will be experimentally positioned off the coasts of southern Mexico and Central America beyond the 200-mile limit and off navigational routes. The principal problem will be anchoring them in the projected areas of 2,000 fathoms (3,600 m) depth. For this, a combination of steel and synthetic cables will be attached to 200 liter drums full of concrete.
(Source: LSB 81-8.)

The Mexican Fish Meal Industry

The Mexican fisheries development policy is aimed at increasing the country's fisheries catch as quickly as possible to meet the domestic food needs of a rapidly growing population. The Department of Fisheries (DEPES), however, is becoming increasingly concerned about the effects of unrestricted fishing along the country's Pacific coast for species which will be reduced to fish meal. DEPES officials recognize that the fish meal industry has lessened the dependence of Mexico's important poultry industry on fish meal imports. Nevertheless, DEPES is concerned about the increasing fishing effort and the utilization of such a large quantity of fish for animal feed instead of for human consumption.

Government officials and executives of the fish meal companies met under the auspices of the Comision Nacional Consultiva de Pesca (CNCP) to work out regulations for the Mexican fish meal industry. The meeting was chaired by Jose Gonzalez Pedrero (CNCP Executive Secretary) and coordinated by Narciso J. Sora Barragan (CNCP Assistant Secretary) and Adrian Roa Navarrete (Chief of the Office of Coordination

of the North Pacific). The Government and the companies reached agreement on several important matters:

1) The fish meal industry accepted the Government's policy of reserving the sardine and anchovy catch primarily for human consumption.

2) The fish meal industry agreed to gradually substitute the nonedible portion of the shrimp by-catch for the sardine and anchovy that are now being reduced to fish meal.

3) The Government promised to restrict authorizations for the construction of new fish meal and oil reduction plants to protect the interests of existing fish meal and oil producing companies.

4) The Government will implement programs which will enable canners to increase production, thus making larger quantities of offal available to the fish meal plants.

5) A study will be made concerning the feasibility of using vessels owned by the fish meal companies to supply canneries.

6) The fish meal companies will study the possibility of shifting some of their production into edible products (fish protein concentrate). (Source: IFR-81/111.)

World Fish Meal and Oil Production

World fish meal production totaled 4.6 million metric tons (t) in 1980, a 5 percent decline from the 4.9 million t produced in 1979 (Table 1). The decline was principally due to production shortfalls in Latin America where increased production by Chile and Ecuador did not make up for sharply reduced production in Peru. The new government in Peru is promoting the production of edible fishery products and has restricted reduction fishing. Projections for 1981 suggest that total world production will be close to 1980 levels.

World fish oil production totaled 1.1 million t (preliminary estimate) in 1980, a 10 percent decline from the 1.3 million t produced in 1979 (Table 1). Sharply reduced production in Peru, which actually had to import fish oil in 1980 for the first time in several years, was primarily responsible for the decline. Projections for 1981 suggest that world fish oil production will be near the 1980 level. (Source: IFR-81/72.)

Table 1.—World production of fish meal[1] and oil (×1,000 t), 1977-81.

Continent and nation	Meal 1977	Meal 1978	Meal 1979	Meal 1980[2]	Meal 1981[3]	Oil 1977	Oil 1978	Oil 1979	Oil 1980[2]	Oil 1981[3]
Africa										
Angola	14	14	14	14	14	5	5	5	5	5
Morocco	12	21	17	16	15	6	9	4	3	3
S. Africa	176	191	170	160	160	26	47	48	50	50
Total	202	226	201	190	189	37	61	57	58	58
Asia										
Japan	805	845	890	850	850	180	297	317	260	275
Pakistan	17	20	20	20	20					
S. Korea	13	13	13	13	13	1	2	1	1	1
Thailand	138	145	180	200	200					
Total	973	1,023	1,103	1,083	1,083	181	299	318	261	276
Europe										
Denmark	337	333	334	370	350	96	79	84	80	75
Finland						4	3	4	4	4
France	18	18	20	20	20	3	3	3	3	3
Iceland	162	201	215	165	165	74	97	90	80	80
Norway	465	332	335	265	265	232	178	189	180	180
Poland	63	52	50	50	50					
Portugal	13	13	13	13	13	5	5	5	5	5
Spain	36	36	36	36	35	6	6	6	6	6
Sweden	8	7	7	7	7	5	5	5	5	5
United Kingdom	78	66	50	50	50	2	2	2	2	2
U.S.S.R	579	580	580	580	580	76	82	82	82	82
W. Germany	49	45	45	45	45	11	13	13	13	13
Total	1,808	1,683	1,685	1,601	1,580	514	471	483	460	455
North America										
Bermuda	47	38	15	15	15					
Canada	50	74	62	57	57	13	8	11	10	10
Mexico	46	50	70	80	80	1	9	9	10	10
Panama	31	18	20	35	30	13	5	5	5	5
United States	303	395	387	375	360	60	134	121	141	135
Total	477	575	554	562	542	87	156	146	166	160
South America										
Argentina	23	23	25	25	25	5	5	5	5	5
Chile	249	369	450	480	500	58	76	109	95	95
Ecuador	83	101	76	100	100	6	10	15	21	21
Peru	497	670	683	475	500	106	129	132	60	65
Total	852	1,163	1,234	1,080	1,125	175	220	261	181	186
Other nations	113	110	110	105	106	10	9	3	9	10
Grand total	4,425	4,780	4,887	4,621	4,625	1,004	1,216	1,268	1,135	1,145

[1]Includes fish solubles, dry weight basis, where separately classified.
[2]Preliminary.
[3]Predicted.
[4]Includes South West Africa and production from factory ships.

The EC Sets A Tariff-Free Eel Quota

The EC Council has established an eel quota of 6,800 t which may enter the EC market tariff-free. The move was made to alleviate the present shortage of supplies to European eel processors.

The primary reason for the decline in the West European eel catch is reported to be increased pollution, especially in the Federal Republic of Germany. Nearly one-third of the tariff-free quota has been allocated to German eel importers.

(Source: IFR-81/138.)

ordered by requesting "Industrial Outlook, Fisheries: Portugal," DIB No. 80-12-013, from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

New NMFS Scientific Reports Published

The publications listed below may be obtained from either the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, or from D822, User Services Branch, Environmental Science Information Center, NOAA, Rockville, MD 20852. Writing to the agency prior to ordering is advisable to determine availability and price, where appropriate (prices may change and prepayment is required).

NOAA Technical Report NMFS Circular 437. Thorson, Lee C. **"Fishery publication index, 1975-79."** May 1981. 117 p.

Abstract

The following series of fishery publications put out by the Scientific Publications Office of the National Marine Fisheries Service (National Oceanic and Atmospheric Administration) in calendar years 1975-79 are listed numerically and indexed by author and subject: Circular, Data Report, *Fishery Bulletin, Marine Fisheries Review*, and Special Scientific Report-Fisheries.

NOAA Technical Report NMFS Circular 438. Cairns, Stephen D. **"Marine flora and fauna of the northeastern United States. Scleractinia."** July 1981. 15 p.

Abstract

This manual discusses the 14 species of scleractinian corals known from the northeastern United States coast from Virginia to Nova Scotia. Following a brief introduction to the general biology and morphology of Scleractinia, an illustrated dichotomous key and two tabular keys are given for these species. An annotated systematic list includes complete geographic and bathymetric ranges, references to pertinent literature, and, for some species, ecological and taxonomic notes. Zoogeographic affinities of the fauna are briefly discussed. A selected bibliography is provided.

NOAA Technical Report NMFS SSRF-746. Dickinson, John J., and Roland L. Wigley. **"Distribution of gammaridean Amphipoda (Crustacea) on Georges Bank."** June 1981. 25 p.

Abstract

The distribution of 97 species of gammaridean amphipods is described for the Georges Bank region, based on 379 samples from 326 stations. A wide variety of sampling gear was used, resulting in representation of both infaunal and epifaunal species. Geographic and bathymetric distributions, and sediment preferences are summarized for each species. The zoogeography of the gammaridean fauna of Georges Bank is discussed, and the most common geographic distribution patterns are described and related to environmental parameters.

Portuguese Fishery Report Available

The U.S. Embassy in Lisbon has submitted a 4-page report describing recent developments in Portuguese fisheries. The text is followed by seven statistical tables on employment, the fleet, fisheries catch, and foreign trade. The report gives a detailed description of the Portuguese fishing industry, as well as an analysis of the Government's fisheries policies.

The Embassy concludes that opportunities for U.S. firms exist in the formulation of joint ventures with Portuguese fish processors, the sale of fishing gear, and exports of certain fish species (such as Alaska pollock, ocean perch, Pacific and Atlantic cod, silver hake, and mackerel).

The report costs $5.00 and can be

Marine Research Under the ICES

"Study of the Sea," subtitled "The development of marine research under the auspices of the International Council for the Exploration of the Sea," has been published by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England. The volume was compiled and edited by ICES Librarian E. M. Thomasson.

As the oldest intergovernmental marine organization in the world, the ICES has been active for nearly 80 years, since its first meeting in Copenhagen in 1902. Its 18 member nations are drawn from both sides of the North Atlantic Ocean, where the Council coordinates marine investigations. That early formation of the ICES is widely regarded as one of the significant events in the history of oceanography.

This volume is a compilation of 40 selected papers, published over the years by leading scientists. They provide a unique survey of important oceanographic and fishery science activities, while giving insight into the thinking and problems facing oceanographic and fishery scientists and administrators during the past 80 years. There is always a problem in winnowing a relative handful of contributions from such a mass of material, but, in sum, the editor has provided a fairly good balance between papers on both historical and controversial marine aspects and specific topics.

The papers are mostly presented in order of date of publication, beginning with the formative years of European marine science and the aims of the ICES. Following are papers on overfishing, migration, stock fluctuations, hydrographic research, pollution, fish farming, science, and fisheries management. Papers were authored by such scientists as Johan Hjort, Otto Pettersson, Johannes Schmidt, Fridtjof Nansen,

Friedrich Heincke, Harald Sverdrup, Sir Alister Hardy, R. J. H. Beverton, Taivo Laevastu, J. A. Gulland, D. H. Cushing, Victor B. Scheffer, and many others.

The papers, with the editor's explanatory notes, illustrate the magnitude and complexity of some of the problems, the advanced thinking of some of the early pioneers in setting the stage for international cooperation in their investigations, and the advances which have been made in marine resource studies.

While not a complete "history" of either the ICES or international marine investigations, these selected readings complement and provide an interesting and valuable background for such existing materials and will be welcomed by anyone interested in the marine sciences and their history. Indexed, the 272-page volume, with 72 illustrations, is available at £25 plus £2.50 postage and handling from the publisher.

American Fisheries Directory Is Revised

Expanded to 886 pages, the second edition of **"The American Fisheries Directory and Reference Book"** has been published by National Fisherman. The first edition was published in 1978.

New listings include fish and seafood processors, producers, brokers, buyers, and wholesalers. The directory also contains new listings of foreign buyers and importers of U.S. seafood products, as well as manufacturers, dealers, and distributors of aquaculture equipment and supplies.

Updated listings include manufacturers of fishing and vessel gear; processing, packaging and handling equipment; dealers and distributors; trade associations; local, regional and national fishermen's organizations; and State and Federal government agencies involved in regulation of the industry. Special services listings include boatbuilders and repairers, naval architects, admiralty lawyers, surveyors, consultants and designers, leasing companies, and other sources of capital for commercial ventures within the industry.

Listings provide names of key personnel, branch offices, products, and the geographic area the company serves.

Other sections of the directory include the latest available data on the industry, up-to-date descriptions of industry-related legislation, and listings of books and periodicals concerning the industry. Copies may be ordered from the publisher, National Fisherman, 21 Elm Street, Camden, ME 04843 at $42 (softcover) or $55 (hardbound), plus $2 postage and handling.

Small Boats and Engines for South Pacific Fishing

"Small Boat Design," subtitled "Proceedings of the ICLARM/SPC Conference on Small Boat Design, Noumea, New Caledonia, October 27-28, 1975," edited by Johanna M. Reinhart, has been published by the International Center for Living Aquatic Resources Management, Manila, Philippines, as ICLARM Conference Proceedings No. 1. The Conference was cosponsored by the South Pacific Commission.

Making the jump from native outrigger canoes to power boats has proven troublesome for many artisanal fishermen in the South Pacific. This volume briefly reviews the results of past fishery development programs, based upon introduced boat design (in Part one), and discusses suitable boat and engine types for the Pacific Island fisheries. Notably, it includes advice by members of the marine industry on applicable boat and engine designs.

Part two of the Proceedings reviewed boats designed for small-scale South Pacific fisheries (both ongoing projects and proposed designs), and Part three discussed factors affecting engine selection (outboards, air-cooled gasoline engines, and jet units vs. direct drive).

The Conference recognized that no single design is adaptable throughout the entire Pacific basin—that boat design must consider the types of fisheries and sea conditions plus the technological and financial capabilities of the various island groups.

The Conference recommended that new small-scale fishing craft be, first, energy efficient. It further advised that propulsion systems be selected only after their reliability, ease of maintenance, and ready supply of spare parts are determined. Standardization of engine model and horsepower range was cited for simplifying parts supply.

Finally, the Conference suggested forming a consultative design group to advise Pacific Island governments on implementing small-scale fishery development programs and to test combinations of hulls and propulsion systems applicable to the South Pacific. The 79-page, $8\frac{1}{2} \times 11$-inch, paperbound volume is sold by ICLARM, MCC P.O. Box 1501, Makati, Metro Manila, Philippines (price not listed).

The Productivity of Virginia's Public Oyster Grounds

Volumes I and II of **"The Present and Potential Productivity of the Baylor Grounds in Virginia,"** by Dexter S. Haven, James P. Whitcomb, and Paul C. Kendall, have been published by the Virginia Institute of Marine Science. Deriving their name from the original "Baylor Study" of 1894, the Baylor Grounds represent all of the public oyster bottoms in that State today. Volume I is concerned with the Rappahannock, Corrotoman, Great Wicomico, Piankatank, York, and Poquoson Rivers, and Mobjack Bay and its tributaries. Volume II describes the James River, Pocomoke and Tangier Sounds, the Bayside and Seaside of the Eastern Shore, and the Virginia tributaries of the Potomac River (Coan and Yeocomico Rivers and Lower Machodoc and Nomini Creeks).

This report, a two-volume set, classifies the public oyster grounds in Virginia in respect to their suitability for oyster culture, first, and secondly for hard clams, soft clams, and brackish water clams. Classification of the various bottom types, from sand through hard oyster rock, was deemed essential to establishing "value." The set of volumes (SRAMSOE No. 243) is available from the Virginia Institute of Marine Science, Sea Grant Communications Office, Gloucester Point, VA 23062 for $10. Volume I includes 167 pages; volume II has 154 pages plus 64 charts.

Pacific Salmon and Hatcheries, Oregon Shrimping, and Florida's Sponges

. . . . **More than 1 million hatchery-bred adult salmon returned** to Alaska's Tutka Bay Lagoon Hatchery and adjacent fisheries last summer, setting new hatchery harvest records in Lower Cook Inlet, the Department of Fish and Game reports. The fish came from a release of 6.3 million young pink salmon in 1980—better than 15 percent survival. "Normally we expect a survival closer to 5 percent at Tutka," said Bob Roys, Director, Fisheries Rehabilitation, Enhancement, and Development. The total pink salmon harvest of 3.1 million in Lower Cook Inlet was the highest ever recorded . . . .

. . . . British Columbia's **Fraser River sockeye and pink salmon runs have greatly exceeded forecasts**, reports the International Pacific Salmon Fisheries Commission. The Commission had forecast a sockeye return of 6 million, but by 4 September 7.6 million sockeye had been noted in catch and escapement. Some late runs were still to be tallied. The Commission had predicted a Fraser River pink salmon run of 9 million fish, but by early September, 12 million pinks had been accounted for in catch and estimated escapement. The pinks were still coming and a revised total return was pegged at 14-15 million . . . .

. . . . Meanwhile, **Alaska's 1981 Bristol Bay salmon season set a series of new records**, with a 25.5 million sockeye catch, according to preliminary Fish and Game Department figures. That beat the old record of 24.7 million set in 1938. District catches were also high, with the 7.5 million-fish Nushugak District catch exceeding the 1905 record of 7.4 million, the Egegik catch of 4.5 million sockeye well over the 1965 record of 3.2 million fish, and the Ugashik District catch of 2 million fish passing the 1922 record of 1.9 million. The total sockeye run was estimated at about 34.0 million fish. New records were also set for chinook salmon as the Nushugak District harvest exceeded all expectations with over 200,000 fish caught by 25 July, beating the previous record of 155,000 set in 1979. The bay-wide chinook harvest of over 245,000 fish was well above the 202,000-fish record reached in 1919 and 1979 . . . .

. . . . **Alaska's hatcheries also released record numbers of fish this year**, according to the Department of Fish and Game's *Bulletin.* Nearly 133 million young salmon, trout, and sheefish were reared and released—almost 2.5 times as many as the previous record. Some leading producers were the Kitoi Bay Hatchery on Afognak Island (over 26 million pink salmon released), the Cannery Creek Hatchery in Prince William Sound (24 million pinks and chums released), and the Russell Creek Hatchery at Cold Bay (15 million pinks and chums let go). The totals are expected to climb even higher in the next few years, since the new hatcheries have yet to reach their full capacity . . . .

. . . . **Alaskan biologists are also optimistic about the 1983 sockeye outlook** for the Kvichak River, one of the major sockeye salmon streams in Bristol Bay, even though 1983 will be a low point in the 5-year cycle of sockeye returns. State scientists now expect the 1983 run will be well above average for a low year ($\sim$4.4 million fish since 1958). Sonar counts of migrating 1980 smolts indicate that, with a 10 percent survival rate, about 17 million fish should return as adults in 1982 and 1983; about 21.5 million fish from this year's migration should return to the river as adults in 1983 and 1984 . . . .

. . . . **With half of the 1981 shrimp season complete**, Oregon shrimp fishermen had landed 16.3 million pounds of shrimp, down just 3 percent from the 16.7 million pounds landed during the same period in 1980, according to the Department of Fish and Wildlife. Through the end of May, landings were up by 2.6 million pounds over last season, and June landings contributed only 3.1 million pounds compared with 6.2 million pounds landed during June 1980. Deliveries dropped from 843 to 424 and were made by 71 fewer vessels. Average catch per trip remained about the same . . . .

. . . . **Sponges, a valuable Florida fishery until the 1940's**, may stage a comeback, according to the Florida Marine Advisory Program *Newsletter.* An exploratory survey of waters off the Florida Keys in Monroe County found them plentiful enough to support relatively large dive-boat operations. Clarification of Florida law to assure legal harvesting by diving could, researchers report, allow the existing Tarpon Springs fleet of five or six boats to continue their traditional method of harvesting off the west Florida coast. Sponge blights in 1939 and 1946 plus heavy harvesting pressure and the introduction of synthetic sponges reduced the once burgeoning fishery. Further study of harvesting methods and fishing economics was also recommended . . . .

. . . . **The University of Alaska has announced establishment of a Fishery Industrial Technology Center** to be located in Kodiak. The Center is to assist Alaskans through training and research in "the most efficient and appropriate technologies for harvesting, processing, and conservation of fish resources," reports the University. Interim director is Donald H. Rosenberg, who remains also as director of the Sea Grant College and as head of the Office for Fisheries. Construction is not expected before 1984, although $175,000 has been allocated for completion of preliminary plans in FY 1982 . . . .

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Citations

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, the year and month and volume and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10-inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 100 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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